Species Status Assessment Report

For the

San Joaquin Valley Giant Flower-Loving Fly

(*Rhaphiomidas trochilus*)

Image by Greg Ballmer

June 8, 2017
US Fish and Wildlife Service
Sacramento Fish and Wildlife Office
Region 8

Executive Summary

Petition History

On June 26, 2014, two entomologists submitted a petition to list the San Joaquin Valley giant flower-loving fly (SJF, *Rhaphiomidas trochilus*) as endangered under the US Endangered Species Act (ESA). We (The US Fish and Wildlife Service, FWS) responded on September 12, 2014, with a letter indicating that emergency listing was not warranted, and that the status of the SJF would be addressed through the normal listing process. On April 10, 2015, we published a 90-day finding in the Federal Register, under section (b)(3)(a) of the ESA. We found that the petition presented substantial information to indicate listing the SJF may be warranted. We have therefore undertaken a status review of the species, as summarized in this Species Status Assessment (SSA). The SSA will inform our 12-month finding under section 4(b)(3)(B) of the ESA, in which we will determine whether listing is warranted.

Species Biology

The SJF is a large fly in the Mydidae family of the order Diptera (true flies). It is referred to as a "giant flower-loving" fly because it is in the genus *Rhaphiomidas*, but it has never been observed sipping nectar. Its known historical range includes eight locations across the San Joaquin Valley, California (CA), but it is now known only from Sand Ridge, a large stable sand dune about 15 miles (mi) (24 kilometers (km)) east of Bakersfield, in Kern County, CA. For over 20 years prior to discovery of the Sand Ridge population in 1997, the SJF had been thought to be extinct. A second, smaller population was also discovered in 1997, about 10 mi (16 km) south of Bakersfield, but no SJF have been observed there since 2006.

SJF larvae have small footlike protrusions like caterpillars, and grow to about 2.5 inches (in) (6.4 centimeters)(cm)). They burrow down to moister sands 6 to 10 feet (ft) (1.8 to 3.0 meters (m)) below the surface, where they prey on the burrowing larvae of other insects. The prey species either feed on other larvae or on the roots of native perennial woody shrubs. After one to two years the SJF larva burrows to near the surface and produces a pupa, within which it metamorphoses into an adult. Adults are strong flyers, 1 to 1.5 in (2.5 to 3.5 cm), and live about 3 days. Their "flight season" lasts about 7 weeks, from mid-August to early October at Sand Ridge. Males seek potential mates by sight, occasionally defending territories from other males. After mating, females lay 5 to 40 eggs in shaded areas, either on the surface of bare sandy soil, or in shallow holes dug into the sand using their abdomens. Eggs likely hatch in about 10 days.

The population at Sand Ridge has been informally estimated at 100 to 1,000 individuals just prior to flight season (when no adults or eggs would be present). No data on population trends is available.

Current and Future Condition of Species

SJF are dependent on areas of inland dune sand, which is rare in the San Joaquin Valley, and have lost seven of eight historically known populations. SJF thus currently lack redundant populations that could maintain the survival of the species if the Sand Ridge population were lost, either due to existing stressors or because of a catastrophic event.

The extirpated historical populations were in areas representative of the breadth of the species' range in the San Joaquin Valley, with slightly different environmental conditions from Sand Ridge. The lost populations had adapted to those conditions, so their loss likely also means the loss of adaptive genetic variations that could help the species adapt to changing environmental conditions in the future.

The single remaining population at Sand Ridge currently has about 106.8 ha (264 ac) of remaining habitat. The resiliency of the population, currently and over the next 50 years, is affected by several factors:

Climate Change: Drought severity has increased since 1900 in conjunction with increasing average temperatures. The most recent drought at Sand Ridge lasted for 5 years and was "exceptional" (the most severe category) for 3 years. This has likely impacted the SJF population due to losses of moist soil substrate and larval insect prey. Drought severity is likely to continue to increase over the next 50 years due to climate change.

Urban and Agricultural Development: Over half the potential habitat at Sand Ridge (including sandy habitat north of highway 58) has been developed, primarily for roads and citrus groves. Urban and agricultural development was also an important factor leading to extirpation of the species at two historical locations. We consider it most likely that approximately 13 ha (32 ac) of remaining habitat will be developed over the next 50 years. This is about one eighth of the currently existing habitat.

Sand Mining: Sand mining was a major cause of the extirpation of a historical SJF population at Antioch Dunes, in Contra Costa County. Two sand mines, one private and one County-owned, currently operate at Sand Ridge, occupying a total of 11.9 ha (29.3) of mined or graded habitat. The smaller County mine has been decreasing its operations for several years, but the private mine has expanded past its permitted area, and has applied to the County to expand further. We consider it likely that the larger mine will expand operations further in the future, over an additional 6.9 ha (16.95 ac). This would remove some of the highest quality remaining habitat, as it is less covered by invasive vegetation.

Vegetation Overgrowth: SJF habitat at Sand Ridge includes large (but unmeasured) areas covered with dense thatches of invasive grasses or other herbaceous plants. These nonnative plant populations interfere with SJF mating activities, intercept water needed by SJF larvae and by native woody shrubs, and eliminate bare ground used for egg laying and pupation. Current impacts are difficult to quantify, but observers have noted SJF are relatively more common on portions of Sand Ridge that have less invasive vegetation overgrowth. Vegetation overgrowth is likely to decrease somewhat in the future due to decreases in precipitation. Such decreases will lead to increased competition for available water, however, so overall impacts of vegetation overgrowth are likely to remain about the same.

Small Population Size: Rough estimates put the current SJF population size at 100 to 1,000 individuals, just before flight season (when all individuals would be larvae or pupae). This translates to an "effective" population size of about 5 to 110 individuals. An effective size of 100 breeding individuals is typically necessary to avoid inbreeding depression. SJF larvae often live two years, so roughly half of the total population would be expected to eclose into breeding adults during any given flight season. The effective size of the SJF population is therefore likely to be well under 100, leaving SJF potentially subject to inbreeding depression. Because adults only live about 3 days, and can eclose at any time over a 49 day flight period, many may eclose on days when very few other adults are available with which to breed. This may lower mating success, and further lower the ratio of census population size to effective population size.

Because of projected habitat losses and increased drought stress, average future population sizes are likely to remain low. Due to chance fluctuations around a low average, the population is likely to become low enough at some point to become subject to serious effects from inbreeding depression or negative stochastic events such as a disease outbreak. The population could then become extirpated before it had a chance to recover.

Off-Highway Vehicles: OHV use has produced noticeable impacts to vegetation at two locations on Sand Ridge totalling about 2 ha (5 ac), as well as on the central trail. OHVs crush woody shrubs important to adults and larvae, and can crush pupae, eggs, neonate larvae, and teneral adults, depending on time of year. OHV use can also remove invasive vegetation, which would benefit SJF if not for other impacts. In the future, OHV use is most likely to increase, potentially leading to further declines in habitat quality over an additional 2 ha (5 ac).

Pesticide Drift: SJF are potentially susceptible to windborne drift from pesticides applied within 200 m (656 ft) of Sand Ridge during or just after flight season (mid-August through mid-October). In 2014, cholinesterase inhibitors were applied heavily, and nicotinoids were applied in moderate amounts, within the four quarter-section areas (402 by 402 m) overlapping Sand Ridge, but have no direct information regarding impacts, if any. In the future, pesticide drift will likely remain roughly at current levels, since nearby lands are likely to remain in agricultural production.

Conservation and Regulatory Actions

Two habitat preserves overlap SJF habitat on Sand Ridge. Roughly 5.7 ha (127.7 ac) of habitat is owned by the Center for Natural Lands Management (CNLM), a nonprofit conservation organization. CNLM lacks funding for land management on the preserve, however. Another 2 ha (5 ac) is owned by CDFW. That preserve currently lacks a management plan, however, and little management is currently conducted except to maintain fencing. The preserves were originally established for Bakersfield cactus (*Opuntia basilaris* var. *treleasei*), an endangered plant that grows in the area.

The private owners of the larger sand mine have been seeking a conditional use permit from the County to expand their operations since 2010. They prepared an EIR, but received comments from CDFW questioning the expected impacts. The matter has been referred to the County Planning Department for further analysis, with no projected decision time.

Cumulative and Synergistic Effects

Certain factors tend to produce cumulative effects due to the similarity of their impacts. For instance, urban and agricultural development, sand mining, and dense overgrowth of invasive vegetation can all remove habitat available to SJF. Less dense invasive vegetation, drought due to climate change, and OHV operation all tend to reduce habitat quality. Direct mortality of SJF can occur due to drift from nearby pesticide application during flight season (which would likely kill adults), and from OHV operation, which could crush eggs, young larvae, pupae, or newly emerged adults, depending on the time of year.

Effects of small population size would tend to be exacerbated by any of the other factors negatively affecting habitat or direct mortality. Sand mining could also further reduce the likelihood of finding mates, because one of the mines at Sand Ridge essentially bisects available habitat, requiring adults to from the separated sections to fly across areas of non-habitat to find each other.

Reduced water availability due to climate change, and OHV operation, both tend to remove invasive vegetation. This positive impact is likely offset by impacts of OHV operation on native vegetation and direct mortality, and by increased impacts of remaining invasive vegetation due to competition for scarcer water.

All these cumulative impacts occur currently and are likely in the future. However, relative impacts may change as additional habitat is removed or changes in quality.

Species Viability

Resiliency

The resiliency of the Sand Ridge SJF population (its ability to persist in the face of environmental stochasticity) is negatively affected by low population numbers, and by various habitat impacts including development, mining, vegetation overgrowth, and drought stress. Because the habitat impacts are likely to continue or increase in the future, the low population numbers are unlikely to significantly improve, and the population will likely remain potentially subject to extirpation from stochastic events or inbreeding depression. Although SJF population estimates were essentially educated guesses from species experts, they are the best data available, and we have no information to suggest they should be higher. A smaller nearby population in Kern County became extirpated around 2006, after development in the area removed some of the remaining habitat.

Redundancy

Population redundancy refers to the extent to which multiple populations exist, such that the loss of one or more populations due to some catastrophic event does not result in the extinction of the species. In the case of the SJF, a single population remains, out of eight populations documented historically.

Representation

Representation refers to the extent to which multiple populations occupy areas of the species range with differing characteristics, thereby potentially maintaining genetic variations and adaptations to those characteristics that could help the species adapt to future changes. SJF populations were originally found across the entire San Joaquin Valley, from the northern and nearly coastal Antioch Dunes, to Sand Ridge in the extreme southeast of the range. As only the Sand Ridge population remains, the range habitat representation in the species is currently very low.

SJF Status Summary Table

Species Needs	Current Condition	Future Condition (next 50 years)
Resiliency: 1. Deep, loose inland dune sand. 2. Bare or lightly vegetated ground. 3. Moist subsurface soil horizon with larval insect prey. 4. Perennial woody or partially woody shrubs with roots extending into the moist soil horizon. 5. Total <u>effective</u> population size ≥ 100 adults during flight season.	**1:** Of 143 ha (343.3 ac) south of Hwy 58, 32.1 ha 20.2 ha (50.0 ac) have been **developed** for agriculture. Another 11.8 ha (29.3 ac) has been converted for **sand mining**. About 106.8 ha (264 ac) of habitat remain. **2, 3, 4:** Much of the remaining habitat is overgrown by **invasive vegetation** – covers open ground, competes with woody shrubs, keeps water out of moist subsurface horizon. **5:** Estimated **<u>effective</u> population size** is 5 to 110 total individuals[1], only about half of which emerge as adults during any given flight season. **5:** Breeding population is spread over **49 day flight season**, but individuals only live 3 days. This lowers effective population size (not accounted for above) and may affect mating success. **5. Pesticide drift** and **OHV use** may directly remove SJF individuals levels. Number affected is unknown. OHV use also affects woody plants (4).	**1:** Current remaining habitat: 106.8 ha (264 ac). Estimated losses of 13 ha (32 ac) due to development, and about 6.9 ha (16.95 ac) due to sand mine expansion. <u>Conservation & Regulatory Actions:</u> *Habitat preserves*: CNLM (53 ha), CDFW (2 ha). Neither has funding for management. *County Conditional Use Permit*: Required for sand mine expansion. On hold due to discrepancies in EIR. Considerable expansion has occurred anyway. **2, 3, 4:** Invasive vegetation may decrease somewhat due to lower preciptation, but will compete for scarcer water, leaving less for woody shrubs & larval prey. Overall impacts may be roughly unchanged. **3, 4:** Reduction of subsurface soil moisture, larval insect prey base, and woody shrubs, due to **climate change**, & increased likelihood of drought. **5:** At some point in 50 years, effective population size is likely to fluctuate below levels at which serious impacts could occur (inbreeding depression, vulnerability to stochastic events), making recovery less likely.
Redundancy: Two or more populations likely to remain resilient for at least 50 years.	One remaining population (of an original 8), with low population numbers indicating low resiliency.	Lack of nearby habitat makes natural colonization of new sites unlikely. No plans currently exist for assisted transplantations.
Representation: Two or more populations representative of environmental variation across the historical range.	The one remaining population is from the extreme southeast of the historical range, and does not represent rangewide variation.	Representation likely to remain unchanged, since new populations are unlikely.

[1] Based on observed ratios of census to effective population size in other insect and non-insect species (Briscoe *et al*. 1992; Frankham *et al*. 1995).

SJF Cumulative and Synergistic Effects Table

Cumulative Factors	Negative or Positive Effect	Type of Effect	Details
Urban and Agricultural Development, Sand Mining, Vegetation Overgrowth.	Negative	Current and Future Habitat Loss	All these factors reduce the total amount of habitat available. Vegetation overgrowth removes habitat when extremely dense; otherwise it reduces habitat quality (see below).
Vegetation Overgrowth, Increased Drought due to Climate Change, OHV Use	Negative	Current and Future Habitat Quality Reduction	Larval prey species likely reduced due to reductions in available water caused by drought and by uptake of water by invasive vegetation. These factors would also tend to reduce moisture available to SJF larvae. OHV use and drought from climate change reduce woody shrubs important to larval prey.
Pesticide Application, OHV Use.	Negative	Current and Future Direct Mortality	Pesticides applied within 656 ft (200m) during flight season would kill adults. OHV operation in SJF habitat during flight season would kill eggs, pupae, neonate larvae, and newly eclosed adults. OHV operation prior to flight season would kill pupae.
Small Population Size, Sand Mining.	Negative	Current and Future Reduced Effective Population Size	The larger sand mine bisects the Ridge, potentially reducing the likelihood of SJF from south of the mine interbreeding with SJF north of it. This would tend to further reduce effective population size and increase difficulties finding mates.
Small Population Size, all other stressors	Negative	Current and Future Depressed Population Numbers	SJF's small population could be due to habitat loss, poor habitat quality, direct mortality, or some combination of those effects. If the population becomes small enough to be affected by inbreeding depression, Allee effects, or stochastic events, those impacts would further reduce population size.
Climate Change, OHV Use	Positive but offset	Current and Future Habitat Quality Alteration	Reduced precipitation due to climate change, and crushing of vegetation by OHVs, will both tend to reduce overgrowth of invasive nonnative vegetation. OHVs also crush native vegetation important to SJF and larval prey, however, and impacts of remaining invasive vegetation may increase due to increased water competition.

Table of Contents

INTRODUCTION

The San Joaquin Valley giant flower-loving fly (*Rhaphiomidas trochilus*; hereinafter "SJF") is a large insect in the family Mydidae (Midas flies). It is endemic (native and restricted) to areas of deep fine sand in the San Joaquin Valley of California, and spends most of its life as a larva, burrowing through the sand and preying on larvae of other insects (Osborne and Ballmer 2014, pp. 3–4). It is not considered a pest species, and is not known to bite, parasitize, or transmit disease to birds or mammals. The SJF has been extirpated from previously known sites in the San Joaquin Valley, and from 1979 to 1997 was presumed to have gone extinct (Powell and Hogue 1979, p. 154; Rogers and Mattoni 1993, p. 32; Osborne and Ballmer 2014, p. 2). It is currently known from a single location called "Sand Ridge," near Bakersfield, CA, which is considerably south of the historical range known prior to the presumed extinction of the species (Cazier 1985, p. 221; Osborne and Ballmer 2014, pp. 1–2).

SPECIES BIOLOGY

Taxonomy

The SJF is one of over 30 species in the genus *Rhaphiomidas*, all of which live in the southwestern United States and northern Mexico (USFWS 2008, p. 7). This genus was originally placed in the family Apioceridae (flower-loving flies) (Cazier 1985, p. 184; Rogers and Mattoni 1993, p. 21), but was moved to the Mydidae family (Midas flies) in 1996 based on morphological characteristics suggesting a closer evolutionary relationship with that group (Yeates and Irwin 1996, pp. 247, 289–290; USFWS 1997, p. 2). For this reason, after 1996 the SFJ has also occasionally been referred to as the "Valley midas fly" (CNDDB 2016, p. 1). Apioceridae and Mydidae are closely related families in the order Diptera, which includes true flies, gnats and mosquitos. Like all Dipterids, the SJF has 2 wings, 2 small knobbed structures called halteres, and undergoes complete metamorphosis from a grublike larva (see Life History, below).

The SJF is closely related to the Delhi Sands flower-loving fly (DSF, *Rhaphiomidas terminatus abdominalis*), which is the only dipterid fly currently listed as threatened or endangered (50 CFR 17.11) under the US Endangered Species Act of 1973 (the ESA; 16 USC 1531 *et seq*.). The reason the SJF but not the DSF is referred to as "giant" likely stems from publication of an article in 1993 that characterized all *Rhaphiomidas* species as "giant flower loving flies" (Rogers and Mattoni 1993, p. 21). The DSF had already been proposed for listing as a "flower-loving fly" in 1992 (57 FR 54547), so its name was not changed. However, a status review of the DSF in 2008 noted that it should actually be called a "giant flower-loving fly" due to its membership in *Rhaphiomidas* (USFWS 2008, p. 12).

Accordingly, the SJF is commonly referred to as a "giant flower-loving fly" because it is a *Rhaphiomidas* species, despite the fact that it is no longer in the "flower-loving fly" family (Apioceridae), and despite the fact that it is not known to feed from flowers (See Life History, below). It is, however, quite large compared to most other dipterid flies (see Life History, below).

Range, Distribution and Habitat

Like all *Rhaphiomidas* species, SJF are associated with arid sandy habitats with a sparse cover of perennial shrubs (Rogers and Mattoni 1993, p. 28; USFWS 2008, p. 7).

The current known range of the SJF is Sand Ridge, in Kern County, CA., about 15 mi east of Bakersfield. Sand Ridge is a "stable sand dune of Pleistocene origin" (Papenfuss and Parham 2013, p. 12) about 900 ft (274 m) high and slightly over 7 mi (12 km) long. Soils maps show dune sand along three portions of the ridge: a 3.5 km (2.2 mi) stretch to the southern end, another 0.5 km (0.3 mi) stretch connected to the first by a narrow band of dune sand about 100 ft (30.5 m) wide and 370 ft (113 m) long, and a third stretch about 1 mi (1.6 km) long towards the northern end, separated from other dune sands by about 1.5 mi (2.4 km). The two more northern portions have been heavily developed with roads, and only the southernmost stretch of dune sand is known to be occupied by SJF. Portions of that have been converted to agriculture or mined for sand, leaving about 3.0 km (1.9 mi) as potentially occupied SJF habitat. The width of this habitat ranges from about 0.16 to 0.32 km (0.1 to 0.2 mi). Large portions of this potentially occupied habitat are either covered by invasive grasses or are relatively rocky, and so may not actually support SJF.

Two ecologically protected areas include SJF habitat on the ridge. The Sand Ridge Preserve is owned by the Center for Natural Lands Management (CNLM), a private conservation organization (CNLM 2016, pp. 1, 5). The preserve itself encompasses 109 ha (270 ac), of which 52.8 ha (130.5 ac) is on the ridge itself and thus SJF habitat (based on GIS analyses). Although CNLM owns the land, it currently lacks funding for management (CNLM 2016, p. 3). The California Department of Fish and Wildlife (CDFW) also maintains a preserve, primarily intended for conservation of the Bakersfield cactus (*Opuntia basilaris* var. *treleasei*), called the Bakersfield Cactus Ecological Reserve - Sand Ridge Unit (CDFW 2011, p. 2; CDFW 2013, p. 5). Based on GIS analysis, 2.1 ha (5.1 ac) of this preserve are on the ridge and thus constitutes SJF habitat. There is currently no management plan for this preserve, and management currently consists primarily of fence maintenance (Tennant 2016, p. 1).

The SJF is historically known from seven additional sites, all in the San Joaquin Valley of California (See Table 1a, below) (Cazier 1985, pp. 240–241; Osborne and Ballmer 2014, p. 2; Ballmer 2016, p. 1). See Tables 1a and 1b, below. One source (Cazier 1985, p. 241) also mentions the observation of two adult females at an eighth historical site ("Rawson Creek") in an unknown county at an elevation of 1,676 m (5,500 ft) in the Sierra Nevada Mountains, but based on the unusual elevation and time of year (early July) these flies were likely a different species (Ballmer 2016, p. 1).

Due to a lack of sightings, the SJF was considered extinct from 1979 to 1997 (Powell and Hogue 1979, p. 154; Rogers and Mattoni 1993, p. 30). In 1997 new SJF populations were discovered at both Sand Ridge and a site 10 mi (16 km) south of Bakersfield (Osborne and Ballmer 2014, p. 2). The site south of Bakersfield was relatively small (about 1 ac (0.4 ha). In 2006, land was cleared on part of the site for an unidentified semicircular structure (possibly a dairy or a stable) that apparently was never completed (Ballmer and Osborne 2016b, pp. 2–5). Land in the area was also cleared and disked for agricultural purposes between 1997 and 2006 (Ballmer and Osborne 2016b, p. 5). No SJF have been seen at the site since 2006 (Osborne and Ballmer 2014, pp. 2).

Table 1a: Historical SJF Locations

Site	County	Total No. Observed	Year First Observed	Year Last Observed	Source*	Extant?
Undisclosed	Merced	1	1892	1892	A	No
Antioch Dunes	Contra Costa	25	1933	1955	B	No
"2 mi E of Antioch"	Contra Costa	1	1974	1974	B	No
Oakdale	Stanislaus	1	1961	1961	B	No
Lindsay	Tulare	1	1920	1920	B	No
Near Ripon	San Joaquin	2	1968	1968	B	No
"10 mi S of Bakersfield"	Kern	24	1997	2006	A	No

Table 1b: Current SJF Locations

Site	County	Total No. Observed	Year First Observed	Year Last Observed	Source*	Extant?
Sand Ridge	Kern	86	1997	2016	A	Yes

***Sources:**

A: Osborne and Ballmer 2014, p. 2. (Note: this source also confirms that the "Antioch" site is Antioch Dunes.)

B: Cazier 1985, pp. 240–241

Life History

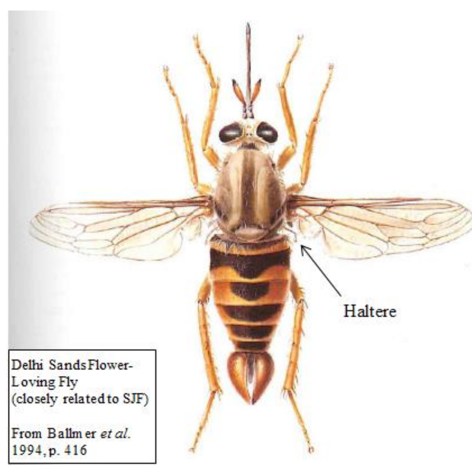
Adults

SJF adults are roughly 2.5 to 3.5 centimeters (cm) long (0.98 to 1.4 inch (in)) not counting a tubelike proboscis (mouthpart) that extends another 0.9 cm (0.35 in) straight out from the head (Cazier 1985. p. 239; Osborne and Ballmer 2014, p. 3). Although several other *Rhaphiomidas* species use their proboscis to sip nectar, the SJF has never been observed to do so (Cazier 1985, p. 239; Osborne & Ballmer 2014, p. 3).

Adult SJF. Female is on left, male on right (Osborne and Ballmer 2014, p. 10)

SJF are primarily gray-brown in color. The backs of their abdomens have bands of black or dark brown alternating with bands of pale yellow or cream color (Cazier 1985, p. 195; Osborne & Ballmer 2014, pp. 3, 10). Males have paired black scale-like structures called hemitergites at the rear of their abdomens covering the genitalia and sticking up at an angle from the rest of the abdomen (Cazier 1985, p. 240; Osborne and Ballmer 2014, p. 10). Female abdomens lack obvious structures at the end of their abdomens (but see discussion of ancanthophorites under "Life History – Eggs" below) (Rogers and Mattoni 1993, Osborne and Ballmer 2014, p. 10). Females are also somewhat larger than males (Cazier 1985, p. 240).

The SJF is a strong flyer, capable of hovering and of fast flight (Cazier 1985, p. 241; Osborne & Ballmer 2014, p. 3). Its wings are transparent, with visible veins (Osborne & Ballmer 2014, pp. 3, 10). Like all insects in the Order Diptera, but unlike many other flying insects such as bees or dragonflies, SJF have only one pair of wings (Hogue 1993, p. 231). The ancestral second pair of wings has evolved in dipterids into very small clublike organs called halteres (see illustration below), which when waved very quickly in a rounded triangular pattern during flight can be used to detect Coriolis effects associated with body rotation (Nalbach 1993, p. 293; Fox *et al*. 2010, p. 3840; Osborne & Ballmer 2014, p. 10). The SJF and other flies use this information for rapid flight control, and are unable to remain aloft without them.



Adult SJF likely only live a few days. They typically die within 3 days when maintained in captivity at room temperature (Osborne and Ballmer 2014, p. 4). Under field conditions, three marked males were found to have remained onsite at the (now extirpated) site south of Bakersfield when checked after 3 hours, but could not be relocated when checked again after two days (Osborne and Ballmer 2014, p. 4). Predation on adult SJF has not been documented, but predators and potential predators of the closely-related DSF include large flies in the *Proctocanthus* and *Promachus* genera, dragonflies, insectivorous birds, and (in the case of a newly emerged adult, as discussed under Pupae, below), Argentine ants (*Linepithema humile*) (USFWS 1997 p. 6). SJF adults are also potentially susceptible to pesticide drift from nearby agricultural fields (see Pesticide Drift, below).

Flight season at the two Kern County locations (including the one remaining location at Sand Ridge) lasts about 7 weeks, from mid-August to early October). At other historical locations the flight season occurred earlier in the year (July to September) (Osborne and Ballmer 2014, p. 4). During flight season, males often fly at low altitudes seeking resting females, or may perch on shrubs to survey the surrounding area (Osborne and Ballmer 2014, p. 6). They may defend the area surrounding such perches by chasing off other males or similarly-sized insects. Observations of a closely related species (*Rhaphiomidas aitkeni*) suggest SJF may have evolved a lek mating system, in which males defend relatively small territories lacking in useful resources, within a larger area called a “lek” (Toft and Kimsey 1982, p. 184). Females then visit the lek to choose from among the potential mates in the area. When a female enters a male’s territory, the male appears to locate her by sight, so dense vegetation, as from invasive grasses or the invasive Sahara mustard plant (*Brassica tournefortii*) may interfere with this critical activity (Osborne and Ballmer 2014, p. 6).

Eggs

Although SJF eggs have been laid in captivity (Osborne and Ballmer 2014, p. 5), we are not aware of any descriptions of those eggs. The eggs of the closely related Delhi Sands flower-loving fly (*R. terminalis abdominalis*) are white, opaque, kidney shaped, and just over a millimeter long (0.04 in) when first laid. Over the course of about a week the egg becomes translucent and the outline of the developing larva becomes visible (Rogers and Mattoni 1993, p. 25). After about 10 days the larva molts inside the egg, and the egg hatches shortly thereafter, typically in the early morning hours (Rogers and Mattoni 1993, pp. 25–27; Osborne and Ballmer 2014, p. 3).

Rhaphiomidas fly species such as SJF lay their eggs on sand, either on the surface or buried slightly below (Rogers and Mattoni 1993, p. 24; Osborne and Ballmer 2014, p. 5). To lay eggs below the surface the female SJF uses comblike structures on the end of her abdomen called acanthophorites to drill a hole down into the sand, expanding her abdomen in the process to approximately twice its normal length (Rogers and Mattoni 1993, p. 24; Van Dam 2010, p. 51; Osborne and Ballmer 2014, p. 3). A captive Delhi Sands flower-loving fly (*R. terminatus abdominalis*) (closely related to the SJF) laid a single egg per hole in this manner, producing 40 eggs in all (Rogers and Mattoni 1993, p. 24). Five captive SJF have been observed to lay from 5 to 38 eggs each, slightly more than half of which were buried, with the rest on the surface (Osborne and Ballmer 2014, p. 5).

Observations of egg laying behavior in three *Rhaphiomidas* species in the wild (*R. undulatus, R. nigricaudis,* and *R. hirsuticaudis*) found all three chose oviposition sites with sandy soil in shaded areas, either within the cover of a woody shrub or within “one to several feet” (0.3 to several m) of the trunk of a woody shrub (Rogers and Mattoni 1993, p. 24). Although “several feet” was not defined, the authors later noted that eclosion sites (where adults emerged from pupae) were always 5 ft (1.5 m) or more from perennial plants, “quite in contrast to oviposition sites” (Rogers and Mattoni 1993, p. 28).

A female of another *Rhaphiomidas* species (*R. painteri*) was observed apparently trying and failing to drill into compact sand with a high gravel content (Rogers and Mattoni 1993, p. 24). She left a small round crater about 3 mm deep (0.1 in), and laid eggs or attempted to do so in three nearby locations before leaving. Two other females of the same species also laid eggs or attempted to do so in the same general area (Rogers and Mattoni 1993, p. 25). No eggs were recovered from any of these sites, implying that finer, more loosely packed sand is necessary for depositing eggs below the surface, and that it may be strongly preferred even for egg laying on the surface. The authors also noted, however, that they found it "virtually impossible" to recover eggs from natural sites in general (Rogers and Mattoni 1993, p. 25), so surface oviposition may possibly still occur on sites lacking fine loose sand.

Larvae

Neonate (recently hatched) SJF larvae are about the size and color of a grain of rice (Osborne and Ballmer 2014, p. 3). They are wormlike, but have welts on the underside of most segments that they use as false legs (Rogers and Mattoni 1993, p. 27).

Neonate larvae of four or five (the report is unclear) other *Rhaphiomidas* species were maintained for several days in captivity (*R. terminatus abdominalis, R. sp. nr. undulatus, R. hirsuticaudis, R. parkeri,* and *R. acton*) (Rogers and Mattoni 1993, pp. 24, 27). The larvae began rooting through the sand with their mouth hooks immediately after hatching, apparently searching for food. However, although offered several potential prey species, the larvae ate none of them, nor did they eat each other when kept in close proximity. All captive larvae died within 15 days of hatching.

Rather than burrowing, the neonate larvae crawled over the sand surface with an "inchworm" type of motion (Rogers and Mattoni 1993, p. 27). In the wild, however, neonate SJF larvae would be expected to burrow at least a few cm (or in) under the surface shortly after hatching to avoid heat and desiccation (Osborne and Ballmer 2016, p. 1). An alternative hypothesis is that neonate *Rhaphiomidas* larvae produce a chemical that entices ants to carry them into their burrows (Ballmer and Mattoni 1998, p. 6). From there, the larvae may either entice the ants to feed them as if they were ant larvae, or they may feed directly on the ants themselves. While this hypothesis is largely speculative, it is based on the observation of a neonate larvae of (*Rhaphiomidas parkeri*) that was carried alive and unharmed by a harvester ant (*Messor sp.*) into the ant's nest (Ballmer and Mattoni 1998, p. 6). Other ants from the colony showed no indications of investigative behaviors often associated with discovery of a new food source.


SJF larva from Sand Ridge (Ballmer 2007, p. 7)

In 2006, entomologists at Sand Ridge, CA. found seven older and much larger SJF larvae burrowing in sandy soils at depths of 1.8 to 3.0 m (5.9 to 9.8 ft) (Ballmer 2007, p. 7; Osborne and Ballmer 2014, pp. 3–4). The larvae were 3 to 6 cm (1.2 to 2.4 in) long and at least 9 months old (see picture below). An attempt was made to raise these larvae in captivity, and although none lived long enough to pupate, one lived another 17 months, making it older than 2 years when it died (Osborne and Ballmer 2014, p. 4). Larvae that were not fed for extended periods lost weight after molting, though they gained weight again upon being fed thereafter (Osborne and Ballmer 2014, p. 4). Some larvae gained and lost weight in this manner through several molts. This suggests that the total lifespan of SJF may vary from one to two years, depending on food availability during the larval stage (Osborne and Ballmer 2014, p. 4).

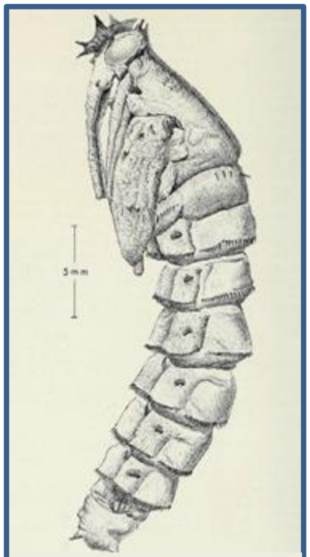
The sand at depths where the larvae were found was noticeably moister than sand above or below. The entomologists were able to maintain the larvae in captivity for several months in sand of similar consistency and moisture content. During that time, the SJF larvae burrowed actively through the sand, preying opportunistically on larvae of various insect species with subterranean larval stages. Prey included an unidentified species of scarab beetle (Scarabaeidae) and a type of beefly (Diptera: Bombyliidae). The SJF larvae also consumed larvae from a paper wasp (*Polistes sp.*) that were manually removed from their nests and buried in the sand. The entomologists noted that many insects have life stages that can occur in the moist soil horizon where the SJF larvae were found, and so would constitute potential prey. Two such examples mentioned were harvester ants (*Messor pergandei*) and Sand Ridge Jerusalem crickets (*Stenopelmatus n. sp.*).

The primary source of nutrition supporting the ecosystem of larval insects on which older SJF larvae feed, is likely to be the roots of native woody and partially woody (suffrutescent) perennial shrubs (Osborne and Ballmer 2014, p. 5). Unlike the invasive grasses and mustards which also grow at Sand Ridge, the roots of such native shrubs can extend down into the moist soil horizon in which older SJF larvae occur, thereby providing sustenance at the base of the food chain for that subterranean ecosystem (Osborne and Ballmer 2014, pp. 5–6). Native shrubs likely to perform this function at Sand Ridge include brittlebush (*Encelia sp*.), California buckwheat (*Eriogonum fasciculatum*), California croton (*Croton californicus*), ephedra (*Ephedra californica*), telegraph weed (*Heterotheca grandiflora*), cheeseweed (*Hymenoclea salsola*), and scale broom (*Lepidospartum squamatum*) (Osborne and Ballmer 2014, p. 6).

Pupae

We are not aware of any recorded observations of SJF pupae, but the pupa of the closely related *Raphiomidas terminatus* is about 3.0 cm (1.2 in), medium brown, and has several recognizable body parts that are also present in the adult, including a clearly distinguished head with sheaths for the eyes and proboscis, a thorax with sheaths for the legs and wings, and a large abdomen with eight well-defined segments, the middle six of which have breathing spiracles on each side (see picture below) (Hogue 1967, pp. 49–52). The pupa also has four pairs of stout, hard spines on its head, four spines on the end of its abdomen pointing away from the body, and a row of small bristle-like spines at the tail end of each of the middle six abdominal segments.

Rogers and Mattoni (1993, p. 28) described *Rhaphiomidas* pupae as being capable of burrowing, possibly by using the spines on their heads to break up the substrate ahead of them. They described pupae as burrowing from deeper underground to just below the surface shortly before eclosion (emergence of the adult from the pupal casing) (Rogers and Mattoni 1993, p. 27). However, subsequent observations have found exuviae from the final larval molt a few cm (1 cm = 0.39 in) below molted pupal casings, thereby indicating that the larva, rather than the pupa, is the lifestage that typically burrows up to near the soil surface so adults can emerge out of the soil (Osborne and Ballmer 2014, p. 3).



Pupal exuviae (molted exoskeleton) of *Rhaphiomidas terminatus* (closely related to SJF), (Hogue 1967, p. 50).

Eclosions have been observed in the wild, in the late afternoon or evening, for two *Rhaphiomidas* species (*R. undulatus* and *R. terminatus terminatus*) (Rogers and Mattoni 1993, p. 27). Pupal exuviae of several *Rhaphiomidas* species (*R. nigricaudis*, *R. acton*, *R. parkeri*, *and R. undulatus*) have also been found in the wild. All such exuviae and eclosions were found in open microhabitats of hardened sand, at least 5 ft (1.5 m) from perennial plants (Rogers and Mattoni 1993, pp. 27–28). It is unclear whether this pattern reflects actual microhabitat preferences, or simply results from a higher likelihood of finding exuviae or eclosing adults in such locations. Newly eclosed (teneral) adults remain soft-bodied and unable to fly for several hours following their emergence (Rogers and Mattoni 1993, p. 27; Osborne and Ballmer 2014, p. 2), while pupae remain near the surface and relatively sessile for the duration of their existence. So both these life-history stages may be more susceptible to predation than at other times. One of the two observed *Rhaphiomidas* eclosions (of a DSF) resulted in the predation of the teneral adult by ants (Rogers and Mattoni 1993, p. 27). The apparent preference by pupating SJF for hardened, open ground might potentially lower the likelihood of being found by such predators, which would normally be expected to find better foraging opportunities closer to shading vegetation.

ECOLOGICAL AND DEMOGRAPHIC FACTORS NEEDED FOR VIABILITY

Ecological Needs of SJF Individuals

The following table summarizes the known resource needs of individuals, as discussed in greater detail under Life History (above).

Table 2: Resource Needs of Individuals

Life Stage	Habitat Resource Needs	References
Eggs and Oviposition Sites	• 2.5 cm (1 in) or more dry surface sand. • Loosely packed sand with low gravel content is necessary for subsurface oviposition, and is likely preferable.	Osborne and Ballmer 2014, pp. 3, 5. Rogers and Mattoni 1993, pp. 24, 25.

	• Within "several feet" of the trunk of a woody or partially woody shrub, or within shrub cover; • Areas shaded at time of oviposition.	
Neonate Larvae	• Dry, loose surface sand into which larvae can burrow at least a few cm (few in) to avoid desiccation; • **Note**: Food source is unknown.	Rogers and Mattoni 1993, p. 27. Osborne and Ballmer 2014, pp. 3, 5. Osborne and Ballmer 2016, p. 1
Older Larvae	• A subsurface soil horizon of fine, relatively moist, loose sand, at depths reachable by the roots of woody or partially woody shrubs (potentially 3 m (9.8 ft) or more). • Larval insect prey in the moist soil horizon, potentially including scarab beetles (Scarabaeidae), beeflies (Bombyliidae), harvester ants (*Messor pergandei*), and Sand Ridge Jerusalem crickets (*Stenopelmatus* n. sp.). • Native woody and partially woody perennial shrubs with roots extending into the moist soil horizon, thereby providing a food source for prey species.	Osborne and Ballmer 2014, pp. 3–6.
Pupae	• May require hardened surface sand, in open, at least 1.5 m (5 ft) from perennial plants.	Rogers and Mattoni 1993, pp. 27–28.
Adults	• Sparse perennial shrubs providing perches for males. • Large areas of bare or lightly vegetated ground, allowing males to see passing or resting females. • **Note**: Food and water are not known resource needs for adult SJF.	Osborne and Ballmer 2014, pp. 3, 6. Rogers and Mattoni 1993, p. 28.

Demographic Needs of SJF Populations

Based on the life histories and needs of SJF individuals (discussed above), SJF populations require non-coastal dune sands with woody or partially-woody shrubs, areas of open sandy ground, and a relatively moist subsurface soil horizon populated by larval insect prey. The extent of such habitat areas necessary for a stable, resilient population is unknown, but should be large enough to support an "effective population size" of at least 100 reproducing adults in order to avoid inbreeding depression (discussed below) (Frankham *et al*. 2014, p. 61). The "effective size" of a population refers to the number of breeding individuals in an "ideal" population (with discrete, non-overlapping generations, equal contribution of all members to the next generation, and free mixing prior to mate choice), that experiences the same amount of genetic drift (random change in gene frequencies) as the actual population (Lande and Barrowclough 1987, pp. 88–89). Because most populations lack many of the characteristics of ideal populations, the actual (census) size of a population is often much greater than its effective size. SJF lack discrete generations because adults may eclose after either one or two years (see Life History – Larvae, above). They also are not freely mixing because adults only live about 3 days, and so can potentially mate only with those adults eclosing within a few days of them over the 7 week flight period (see Life History – Adults, above). The ratio of effective population size to census population size in a population of fruit flies (*Drosophila spp*.) brought into captivity from the wild was found to be 0.051 (Briscoe *et al*. 1992), while the average ratio of effective population size to census size across 102 species of wildlife was found to be 0.11 (Frankham *et al*. 1995). If SJF have a ratio in that range, then in order to avoid inbreeding depression they would need habitat capable of stably supporting from 909 to 1,961 or more reproducing adults.

Inbreeding depression is caused by loss of beneficial gene variants (alleles) in small populations, leaving deleterious alleles as the only remaining variants of a given gene (Soule 1980, pp. 157–158). It also results from increased mating between closely related individuals in small populations, thereby increasing the likelihood that both parents pass on the same recessive deleterious alleles to their young (Lande and Barrowclough 1987, p. 96). Inbreeding depression can cause abnormal sperm, congenital defects, and lowered disease resistance (Soulé 1980, pp. 157–158; Gilpin 1987, p. 132; O'Brien 2003, pp. 62–63).

SJF also require sufficient habitat to allow population sizes large enough to recover from harmful events such as storms, droughts, or fires (environmental stochasticity) (Gilpin 1987, pp. 132–134). We discuss the potential impacts of such factors below, but we lack information regarding the amount of habitat (and resulting population size) that a single population would require to minimize such risks. In the absence of population viability analyses or similar information, we estimate that SJF populations require sufficient habitat to absorb losses of 10 percent and still remain above the minimum size required to avoid inbreeding depression. This would mean sufficient habitat to support a population size of 1,000 to 2,157 reproducing adults.

Small populations may also be at risk due demographic stochasticity (chance variations from optimal sex ratios or in reproductive output), or from Allee effects (inability of individuals to locate acceptable mates) (Lande 1998, pp. 353, 357; Stephens *et al*. 1999, p. 188; Møller and Legendre 2001, pp. 27, 31–33). Populations large enough to avoid long-term impacts from inbreeding depression or environmental stochasticity would normally also be large enough to avoid impacts from these factors.

Additional Demographic Needs of the Species

To maintain viability, the SJF needs multiple resilient populations so that loss of any single population will not result in extinction of the species. Rather than clustering in a single portion of the range, the multiple populations should be representative of differing environmental conditions across the historical range, so that genes adaptive to those conditions are not lost. The maintenance of such genetic variation increases the likelihood that the species will be able to adapt quickly to changing environmental conditions.

For instance, the current annual precipitation at Bakersfield, CA (near Sand Ridge) is 16.4 cm (6.45 in), whereas at Antioch, CA, (near the historical SJF site at Antioch Dunes) the annual precipitation is more than twice that (33.9 cm, 13.35 in) (US Climate Data 2017, pp 1–2). These are the lowest and highest precipitation rates, respectively, of all known historical sites (US Climate Data 2017, pp 1–4). Antioch also sits in a "Northern California inland" climate zone, with colder marine-influenced air (Williamson 1979, pp. 16–18), while Sand Ridge is in a "Central Valley thermal belt" climate zone, with higher summer temperatures and more sunshine (Williamson 1979, pp. 14, 19). The Oakdale and Lindsay sites were also in a "Central Valley thermal belt" zone, while the Ripon site was in a "Northern California inland" zone, like Antioch (Williamson 1979, pp. 14, 17, 18–19). The SJF site south of Bakersfield appears to have occupied a "Central Valley cold-air basin" zone, characterized by somewhat colder air than the "Central Valley thermal belt" zone occupied by nearby Sand Ridge (Williamson 1979, pp. 14, 19). These climatic differences can potentially affect the species of insect prey species and of woody or partially woody plant species in the area, potentially leading to differing adaptations in SJF populations occupying each area. Because only the Sand Ridge SJF population now remains, the species now lacks the representation of genetic differences across its range that may once have existed.

CURRENT CONDITION OF THE SPECIES

<u>Urban and Agricultural Development</u>

Current Range

Of the three areas of dune sand at Sand Ridge totaling 6.0 km (3.7 mi) (both north and south of Hwy 58), over half (about 3.1 km (1.93 mi)) has undergone urban or agricultural development. Another 0.4 km (0.25 mi) has been converted to a sand mine (see Sand Mining, below). Development includes the entire northernmost area of dune sand (2.09 km (1.3 mi)), converted and graded for Bena Road and a railroad track. About 0.8 km (0.05 mi) was graded or paved for highway 58 in the middle section of dune sand, and another 0.16 km (0.1 mi) has noticeably different vegetation and may consist of fill dirt. The southernmost area of dune sand includes two areas converted to citrus grove: one about three quarters of a kilometer (0.5 mi) long, and the other about one third of a kilometer long (0.2 mi).

Historical Range

The locations of two historically occupied sites are known: Antioch Dunes and "10 mi S of Bakersfield" (see Table 1a, above). The general area of a third such site is somewhat determinable: "2 mi E of Antioch." Of these three, urban and agricultural development appears to have played a major role in the extirpation of the sites east of Antioch and south of Bakersfield. It may also have contributed to the extirpation of the Antioch Dunes location.

To get a general sense of the extent to which potential SJF habitat may have been affected by urban and agricultural development, we mapped polygons of potential habitat in the San

Joaquin Valley using NRCS soil survey data to identify locations with sandy, well-drained, gently sloping soils. We then visually inspected each polygon using aerial imagery from 2014, characterizing it as potential habitat, or converted to agricultural or urban uses. We also confirmed that our soils criteria identified the Sand Ridge and Antioch Dunes locations as potential habitat (see habitat map, below). The maps show that all land roughly 2 mi (3.2 km) east of Antioch with the correct soils has been converted either to agricultural fields or housing developments, with the exception of a small area of potential habitat (1.72 ha (4.2 ac)) at the Big Break Regional Shoreline Park in Oakley, CA. Since the SJF has not been recorded in that general area since 1974, we consider it likely that its historical breeding site has been developed.

The site "10 mi S of Bakersfield" was not captured by our map based on SJF soils criteria. Presumably that site consists of an inclusion of dunelike soils too small to have been noted in the NRCS soils data. However, comparisons of aerial photography of the location show that large portions of the site (which was only about 0.4 ha (1 ac) to begin with) were graded prior to 2009, but after June 4th, 2005. That development appears to have been the most direct cause of extirpation of SJF at the site, which were last seen there in 2006 (Ballmer and Osborne 2016b, pp. 2–3, 5). After grading, construction of a circular structure of some sort, possibly a dairy or stable, was begun but never completed.

The Antioch Dunes originally extended 9 km (5.6 mi) along the southern bank the San Joaquin River near Antioch, California, but were much reduced by sand mining (discussed below) and urban and agricultural development (USFWS 2002, pp. 17). The dunes are now restricted to portions of the 22 ha (55 ac) Antioch Dunes National Wildlife Refuge (NWR) (established in 1980), and to an adjacent 4.9 ha (12 ac) property owned by the Pacific Gas and Electric Company (USFWS 2002, p. 17). The dunes originally reached heights of 36.6 m (120 ft), but would have been much lower and easier to build on in places that had been mined. Development on the dunes outside the current area of the refuge, has included a vineyard, recreational cottages, wharfs, a shipyard, railroad and transmission lines, a wastewater treatment plant, and a gypsum plant (USFWS 2002, pp. 7-10, 17). These areas might have already been mined for sand prior to development, however, so it is unclear whether loss of habitat in these areas is attributable to development or mining.

Based on our map of potential SJF habitat and current land uses across the San Joaquin Valley, approximately 17.7 percent of the habitat originally capable of supporting SJF still remains. The rest has been converted to agricultural and urban uses. However, we have no information regarding what portion of habitat originally capable of supporting SJF was ever actually occupied by SJF.

Map of Remaining Undeveloped Potential SJF Habitat

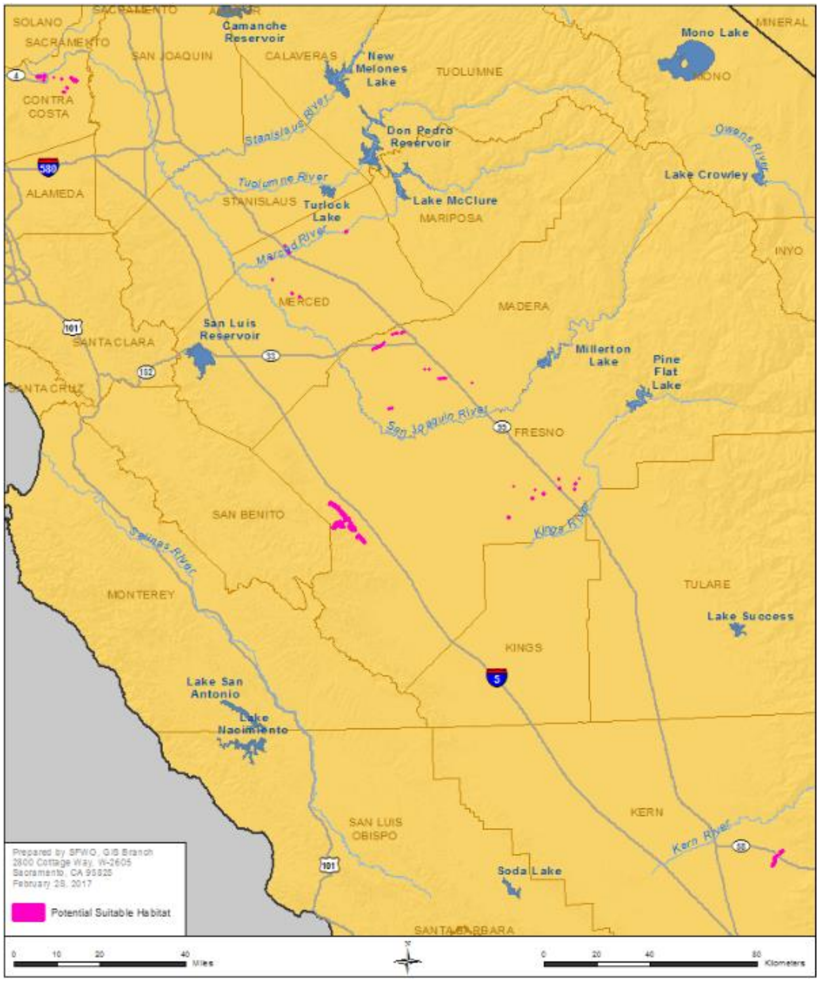


Table 3: SJF Potential Habitat, Current and Historical

Landcover Type	Acres	Ha
Habitat with soils amenable to SJF, but with incompatible landcover (i.e. wetlands or forest)	6.7	2.7
Potential SJF Habitat Historically Present	22,581.2	9,138.3
Urban (buildings and surrounding bulldozed grounds)	5,670.5	2,294.8
Agricultural production (including associated buildings and roads)	12,612.1	5,103.9
Fallow agricultural lands	306.0	123.8
Potential SJF Habitat Currently Present.	**3,992.6**	**1,615.7**

Vegetation Overgrowth

Current Range

Sand Ridge has been described as a "stable sand dune of Pleistocene origin" (Papenfuss and Parham 2013, p. 12). It may thus have formed in a manner similar to Antioch Dunes, where glacially eroded sands from the Sierra Nevada Mountains were washed into floodplains, and then blown onto dune fields between 10 and 40 thousand years ago (Atwater 1982, p. 3). There are no obvious areas of new sand deposition on the ridge currently, and significant deposition of new sand would be unlikely since the glaciers are now gone and many of the floodplains are now diked. Unlike on a coastal dune, vegetation growth on Sand Ridge therefore remains unrestricted by unstable substrate or by the deposition of large amounts of new sand. Vegetation growth is instead limited primarily by the low annual precipitation rate of the semi-arid region (16.4 cm (6.45 in) (US Climate Data 2017, p. 2)). Certain invasive plant species have shown themselves capable of overgrowing large areas of otherwise bare sand, despite the low precipitation rate, however.

Portions of Sand Ridge are currently covered by dense thatches of ripgut brome (*Bromus diandrus*), a nonnative invasive grass, and Sahara mustard (*Brassica tournefortii*), a nonnative invasive herb (Calflora 2000, p. 1; Cypher *et al*. 2011, p. 10; CNLM 2016, p. 3). Additional nonnative invasive plants in the area include red brome (*Bromus madritensis ssp. rubens*), and wild oats (Avena spp.) (Cypher *et al*. 2011, p. 8; Osborne and Ballmer 2014, p. 6). These nonnative plant populations occupy areas of bare sand that would otherwise be used by SJF adults for egg laying and by larvae as pupation locations (see Resource Needs of SJF Individuals, above). They may also interfere with the ability of males to visually locate and mate with females (Osborne and Ballmer 2014, p. 6). Botanists surveying for Bakersfield cactus (*Opuntia basilaris var. treleasei*) in 2010 and 2011 noted that nonnative grasses in the area grew densely enough to interfere with their own ability to locate the cactus plants (Cypher *et al*. 2011, pp. 12–13).

Nonnative, invasive plants also compete for space, water, and nutrients with native plants (CNLM 2016, p. 3; USFWS 2002, p. 7,25,34,36-37,40; Cypher *et al*. 2011, p. 15). The insect larvae on which SJF larvae feed obtain their own nutrition from the deep roots of woody and partially woody native plants (see Life History – Larvae, above), so competition-based impacts to those deep-rooted native plants could also negatively impact SJF. Osborne and Ballmer (2014, pp. 5–6) noted that nonnative invasive grasses and mustards appeared to be more common on the northern portions of Sand Ridge, whereas woody perennial shrubs and areas of bare soil appeared more common on the southern third of the site. They noted that SJF were also apparently much denser on the southern third (Osborne and Ballmer 2014, p. 6).

Historical Range

Antioch Dunes: This area is comprised of glacially eroded sand carried downriver from the Sierra Nevada and deposited on nearby floodplains and then blown by summer winds to form dunes 10 to 40 thousand years ago (Atwater 1982, p. 3; USFWS 2002, p. 18). As with Sand Ridge, discussed above, that sand deposition process no longer functions. Accordingly, little to none of the sand lost historically from the Dunes due to mining operations has been naturally replenished.

The USFWS and the Pacific Gas and Electric Company (PG&E) attempted to restore the Dunes to some extent in 1991 and 1992 by importing 7,000 cubic yards (5,352 cubic m) of riverine sand to create new dunes (USFWS 2002, pp. 39–40). They also sculpted and replanted the new dunes in an attempt to reestablish historical dune communities. Existing sandy substrate was moved and re-sculpted in some areas of the Antioch Dunes NWR for the same reason. Unfortunately, within ten years, nonnative vegetation had heavily recolonized the restored dunes, and appeared to be outcompeting the native species (USFWS 2002, p. 40). Invasive species of primary concern include ripgut brome (*Bromus diandrus*), yellow starthistle (*Centaurea solstitialis*), vetch (*vicia spp.*), and tumbleweed (Russian thistle, *Salsola tragus*) (USFWS 2002, p. 25).

The encroachment of invasive nonnative vegetation, and consequent crowding out of native plants, has been an ongoing problem at Antioch Dunes since before the Antioch Dunes National Wildlife Refuge was first opened in 1980 (USFWS 2002, pp. 7, 25, 34, 36-37). That encroachment may be the most direct explanation for the loss of bare-sand areas used by dune insects such as the SJF. A study of insect extirpations at Antioch Dunes identified invasive vegetation and lack of disturbance as the primary causes of insect extirpations at the site (USFWS 2002, p. 27).

Beginning in 2013, the USFWS, began working with the California Department of Fish and Wildlife, the US Army Corps of Engineers, and the Port of Stockton to restore dunes on the refuge using sand dredged nearby from the San Joaquin River (Bergamin 2013, p. 2). A sand-water slurry, dredged to maintain a deepwater channel for ships, was pumped onto the refuge, where the sand was separated out and sculpted into dunes. Forty thousand cubic yards (30,582 cubic m) of sand were added to the refuge in 2013, and the process is expected to continue through roughly 2023.

<u>Other Historical Sites</u>: Impacts from vegetation overgrowth at other historical SJF locations (see Table 1a, above) are somewhat difficult to determine because existing records do not indicate exactly where the sites were located (Cazier 1985, pp. 240–241). However, invasive ground-covering vegetation such as ripgut brome and red brome are considered invasive throughout California, while wild oat species (Avena spp.) are invasive from the Sierra Nevada Mountains west (Cal-IPC 2006, pp. 7–8), and so may have affected SJF at those locations.

<u>Sand Mining</u>

Current Range

The roughly 3.5 km (2.2 mi) of potential SJF habitat at Sand Ridge (the southern portion of the ridge as discussed under Range and General Habitat, above) is separated, about a third of the way from the southern end, by two operating sand mines, one just north of the other (Caliente 2013, p. 1-1; Blasé 2017, p.1). The larger and more northerly of the two is privately owned, extends roughly the width of the ridge, and currently occupies approximately 0.4 linear km (0.2 mi) of the total 3.5 km (2.2 mi) of potential habitat. This amounts to approximately 9.6 ha (23.8 ac) of mined or graded ground. The conditional use permit for this mine authorizes the removal of 200,000 tons of material per year, to a maximum depth of 25.6 m (84 ft).

The smaller sand mine is about 100 m (328 ft) to the south, is owned by Kern County, and (along with associated roads) occupies about 3.6 ha (9.0 ac) in the middle of Sand Ridge. Rather than extending across the entire ridge, the second mine currently leaves about 30 m (98 ft) of undisturbed habitat to its west and 20 m (66 ft) to its east. An SJF female was sighted in the 30 m (98 ft) of habitat to the west of the mine in 2016 (Tarr 2016, p. 1). The amount of sand removed from the County-owned mine has been decreasing for several years (Blasé 2017, p. 1). Both mines have been in operation since 1982 (Caliente 2013, p. 1-1).

Operation of either sand mine involves removal of woody and partially woody vegetation required by SJF larvae and adults, as well as the removal of successively deeper layers of sand required by larvae and pupae. SJF require surface layers of open sand for egg-laying and pupation, and deeper layers of moister sand for growth of larvae (see Resource Needs of SJF Individuals, above). Moisture content in those deeper layers may also be reduced indirectly, both by removal of higher insulating layers, and because water will tend to seep from surrounding areas to replace moisture lost at the mine site. Removal and transport of sand is also likely to have crushed or removed SJF larvae and pupae. Sand mine operation has thus removed habitat at Sand Ridge, and is likely to have directly killed numerous SJF as well.

The existing conditional use permit for the larger sand mine (required because the land is zoned for agriculture) authorizes mining activities on 5.3 ha (13.05 ac) (Caliente 2013, p. 1-1). In 2004 the mine owners applied to expand the mine by 6.9 ha (17 ac), but that expansion was never approved (OMR 2013, p. 1). Despite this, aerial imagery indicates the mine had expanded to about 7.7 ha (19.0 ac) by 2009, to 8.9 ha (21.9 ac) by 2012, and to 9.6 ha (23.8) ac by 2014.

In 2013, the owners of the sand mine submitted a draft environmental impact report (dEIR) in support of an application to expand their operations to 17.5 ha (43.25 ac) (Caliente 2013, pp. 2, 1-1). The Kern County Planning and Community Development Department received several comments critical of various aspects of the proposal, including letters from three entomologists noting potential impacts to the SJF (among other insects) (KCPCDD 2014, pp. 88–96). The California Department of Fish and Wildlife also commented, noting the unauthorized expansion of mining activities, mapping discrepancies, mitigation obligations in the original permit that did not appear to have been met, and potential impacts to various protected species (CDFW 2013, p. 4–14). The proposed expansion was referred back to Kern County Planning Department staff for further analysis (KCPCDD 2014, p. 1), and has not been acted on since that time (Rojas 2016, p. 1).

Historical Range

Antioch Dunes originally covered a much larger area, but was mined extensively for sand beginning in the 1880s, eventually reducing the dune area to portions of the 22 ha (55 ac)

Antioch Dunes NWR and to an adjacent 4.9 ha (12 ac) property owned by the Pacific Gas and Electric Company (USFWS 2002, p. 17). Dune height has also been reduced, from 36.6 m (120 ft) to 3.0 to 15.2 m (10 to 50 ft) (USFWS 2002, p. 21). Sand mining was particularly extensive from 1933 to 1939 (USFWS 2002, p. 27), while the number of SJF sightings at Antioch Dunes decreased from 12 in the 1930s to 3 in the 1940s and 2 in the 1950s (Cazier 1985, pp. 240–241). Sand mining may thus have contributed to the sharp drop in sightings in the 40s as compared to the preceding decade. The long history of sand mining at Antioch Dunes has removed large areas of habitat, and may thus have played a primary role in the extirpation of SJF at the site, either due to direct impacts such as removal of eggs and larvae, or else by bringing available habitat below the point where it could support a stable population (see Small Population Size, below).

We are not aware of sand mining operations at any of the other six historical SJF sites, but we only know the location of one of those sites ("10 miles south of Bakersfield").

Off-Highway Vehicles (OHVs)

Current Range

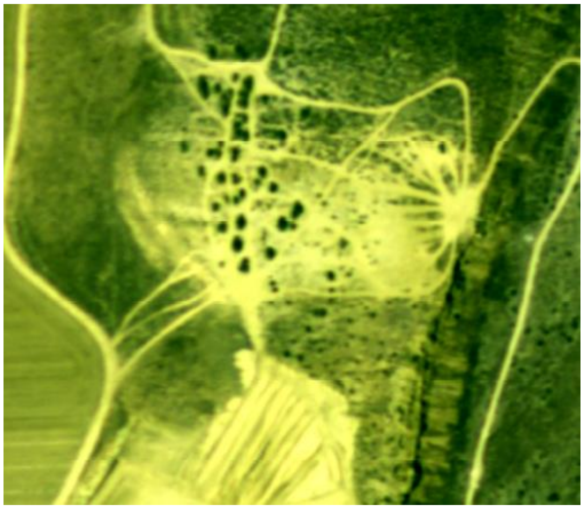
Extensive OHV operation can remove the woody and partially woody shrubs whose roots provide nutrition for larval SJF prey species. Impacts on shrubs are likely to occur both from direct breaking or crushing, and because OHVs compact soil, reducing the availability of water for the plants' roots (USGS 2007, p. xii). OHVs are also likely to directly injure or kill SJF pupae, which typically position themselves just below the surface in open areas of hardened sand, such as dirt roads (Van Dam 2017, p. 1). Although the pupae would have some protection, being slightly under the surface of hardened sand, OHV tires tend to dig into such areas for traction whenever the vehicle accelerates, swerves, or brakes. SJF eggs, recently hatched larvae, and recently eclosed adults (which cannot fly for several hours) are typically found on or just below the surface, and so would also be highly vulnerable to direct impacts from OHVs operating during times of the year when they were present (see Life History, above). Finally, the eggs, pupae, or adults of insects whose larvae constitute SJF prey might also be crushed or injured by OHVs, thereby lowering their populations and leaving SJF larvae with a reduced food source (Van Dam 2017, p. 1). At the Algodones Dunes in southern California, a comparative study found 858 dune beetles where OHV operation was prohibited, but only 54 in nearby areas subject to high OHV use (Van Dam and Van Dam 2008, p. 415). Diversity of dune beetle species was also significantly lower in the OHV areas.

Sand Ridge Preserve, in the northern portion of the SJF habitat at Sand Ridge, is subject to occasional illegal OHV use (CNLM 2016, p. 3). CNLM has posted a sign indicating such use is prohibited, but lacks funding to fence the preserve or effectively police the area (Warrick 2017, p. 1). Aerial imagery shows some OHV trails at the northern end of the preserve, but most such trails in the area appear to be just north of the preserve itself. Overall area in this northern portion of the Ridge containing OHV trails is roughly 1.0 ha (2.5 ac). The trails are comparatively lacking in invasive vegetation, which in itself is an effect that is beneficial to SJF (see Vegetation Overgrowth, above). If OHV numbers, locations, and dates of use could be regulated so closely as to prevent extensive damage to woody shrubs or direct injury to SJF, then their overall impacts might be positive. For instance, the Antioch Dunes National Wildlife Refuge (NWR) management plan notes that increased soil disturbance would help prevent overgrowth of invasive non-native vegetation at the refuge, and lists OHV operation as one of the disturbance mechanisms that might be tried in areas that are currently overgrown and lacking native plants and insects (USFWS 2002, p. 52). This has not actually been carried out at Antioch Dunes NWR, however, and the likelihood of successfully doing something similar at Sand Ridge is low due to lack of management funding.

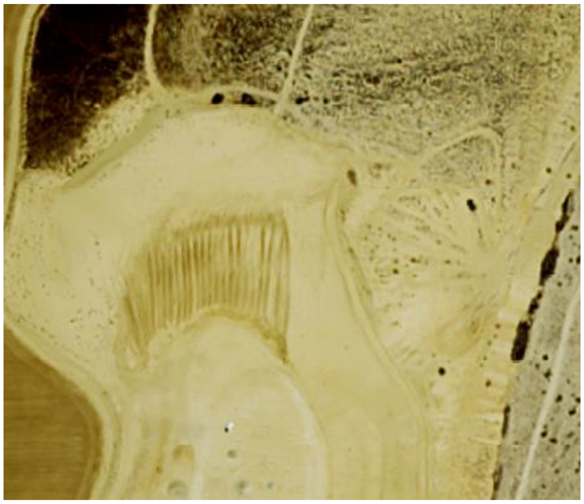
Another area of Sand Ridge at which impacts from OHV use are evident is in the southern portion of the Ridge, just northeast of the privately operated sand mine (see Sand Mining, above). The draft environmental impact report, submitted in support of expanded mining operations, noted that in an area just north of their current sand mining operations, "[t]he presence of off-road vehicles and the resulting accelerated wind erosion have led to a sparse shrub density on an unstable dune" (Caliente 2013, p. 3-17).

Aerial imagery from 2005 and 2014 (1:2,000 resolution) shows numerous dirt tracks and an apparent loss of woody and partially woody shrubs in the described area consistent with OHV activity. The affected area is north of the sand mine in the 2005 imagery, and just east of the expanded sand mine in the 2014 imagery below. Current (2014) size of the affected area is approximately 1 ha (2.5 ac). Loss of vegetation appears more complete in this area than in the area north of the CNLM reserve.

2005



2014



Historical Range

We have no records specifically showing heavy off-road vehicle (OHV) use at any of the known historical SJF areas.

Small Population Size

Current Range

The size of the SJF population at Sand Ridge is difficult to accurately determine because a substantial percentage at any one time would consist of larvae, deep underground (Ballmer and Osborne 2016a, p. 2). Population size at Sand Ridge has not been statistically evaluated, but an informal estimate provided by two entomologists familiar with the species and the area is 100 to 1,000 pupae and larvae just prior to flight season (when there would be no adults or eggs) (Osborne and Ballmer 2014, p. 5; Ballmer and Osborne 2016a, pp. 1–2). Assuming roughly half this number successfully ecloses into adults in a given year (the other half remaining as larvae due to the 1 to 2 year larval life span), and assuming all of the adults live to mate and lay eggs, that would result in between 50 and 500 successfully reproducing adults in a given year.

The life span of each of these 50 to 500 reproductive adults is about 3 days during a flight season of about 7 weeks (see Life History – Adults, above). If adults eclose fairly evenly across the flight season, for one adult to potentially mate with another specific adult, it would have to eclose within a 5 day period: from 2 days prior to 2 days after the day on which the other eclosed. Adults eclosing outside of that 5 day period would not be available as potential mates. There are roughly 10 such 5-day periods during the 7-week flight season, so about 90 percent of the population would be unavailable to any given individual seeking to mate. In general terms, this would tend to reduce the effective size of the population. For the 100 to 1,000 SJF at Sand Ridge, it would result in an available breeding population at any given time during the flight season of between 5 and 50 individual adults. With a 50:50 sex ratio between 2.5 and 25 flies of the opposite sex would be available as potential mates at any given time. Variations in the sex ratio at the lower end of that range could produce situations in which adults eclosing on a given day have no potential mates because every available adult is of the same sex.

Problems of eclosure overlap may also produce Allee effects (see Resource Needs of Populations, above), by negatively affecting the ability of individuals to locate potential mates, even if such are available somewhere on the range. SJF males apparently establish and defend territories (see Life History – Adults, above), so their ability to mate would depend on whether a female finds and enters their territory. Occupied habitat on Sand Ridge stretches across about 3.0 km (1.9 mi) (see Range and General Habitat, above) not counting the two sand mines that create a roughly 0.5 km (0.3 mi) gap (see Sand Mining, above). The estimated number of adults flying at Sand Ridge at any point during the flight season (between 5 and 50 individuals) would result in population densities of between 0.047 – 0.477 adults per hectare. It is unknown how adults search for potential mates and whether this density would interfere with mate searching behaviors.

The issues discussed above assume that eclosing adults are distributed fairly evenly across the flight season. If eclosion times instead tend to cluster around one or two shorter periods, then the difficulties in finding mates would be lessened for most individuals in the population, but increased for those individuals eclosing during non-peak days. The estimated length of the flight season is based on observations of adult SJF by Cazier (1985, pp. 240–241) and Osborne and Ballmer (2014, p. 4), so SJF do appear to potentially eclose on any given day during the season, but Osborne and Ballmer (2014, p. 4) note there has never been a systematic, season-long survey of adults, and that the season itself might vary somewhat from year to year. On the other hand, we have no records of any observers ever seeing more than three SJF on any given day, either historically (Cazier 1985, pp. 240–241) or recently (Tarr 2016, p. 1; Sloan 2016, pp. 1, 6).

In addition to demographic effects associated with small populations, the population of SJF at Sand Ridge may be at risk of negative fitness effects due to inbreeding depression. As a rule of thumb, inbreeding depression becomes a concern at effective population sizes of 100 or less (Frankham *et al*. 2014, p. 61). The ratio of effective population size to census population size in a population of Drosophila brought into captivity from the wild was found to be 0.051 (Briscoe *et al*. 1992) and the average ratio of effective size to census population size across 102 species of wildlife was found to be 0.11 (Frankham *et al*. 1995). Applying these ratios to the estimated range of the entire SJF census population (not just breeding adults) results in estimates of effective population size of 5 to 110 individuals (100 * 0.051 to 1,000 * 0.11). If similar ratios of effective size to census size of the population hold true for the SJF, then its effective population size would be at or below 100, and so at risk of inbreeding depression. Studies investigating the specific ratio of census to effective population size have not been conducted nor have investigations examining whether direct evidence of inbreeding depression exists for SJF.

Historical Range

We have the exact site locations for only two of the seven sites at which SJF were historically present (see Table 1a, above). Those were Antioch Dunes and the site "10 miles south of Bakersfield." As discussed under Urban and Agricultural Development, above, the last sighting of SJF at the site "10 miles south of Bakersfield," in 2006 occurred shortly after habitat at the site was graded for a structure that was never completed (Ballmer and Osborne 2014, p. 2; Ballmer and Osborne 2016b, p. 2–3, 5). Final extirpation of SJF at that site therefore appears to have directly resulted from urban development rather than from issues related to reproduction dynamics in small populations.

In the case of Antioch Dunes, however, the area was heavily mined for sand in the 1930s, and SJF sightings decreased over the ensuing years until the final sighting in 1955. It is therefore possible that mining served to remove habitat, and to thereby lower population numbers and resiliency, but that final extirpation was caused by inbreeding depression, failure to find mates, and chance harmful events as discussed above.

Pesticide Drift

Current Range

Although pesticides applied in the Central Valley of California (of which the San Joaquin Valley comprises the southern portion) have been detected in the Sierra Nevada Mountains, several miles away (LeNoir *et al*. 1999, pp. 2715, 2721; Davidson *et al*. 2002, pp. 1588, 1597–1598), this is due to volatilization of the chemicals into the atmosphere due to warm Valley temperatures, and subsequent deposition due to condensation in the cooler temperatures of the mountains (LeNoir *et al*. 1999, pp. 2715). Sand Ridge is at low elevation, and so would not likely receive measurable depositions of volatilized pesticides.

However, windborne drift of non-volatilized pesticides such as malathion (a cholinesterase inhibitor) can be lethal to non-target invertebrates at distances of up to 200 m (656 ft) from application (Newhart 2006, p. 5). Pesticide application data for 2014 shows heavy application (greater than 524 lbs) of cholinesterase inhibitors within all four quarter-section areas (402 by 402 m areas) that overlap Sand Ridge (CEHTP 2016, p. 2). Moderate levels (16 to 51 lbs) of neonicotinoid pesticides were also applied within three of those four quarter-section areas (CEHTP 2016, p. 1).

The existence or extent of impacts from pesticide drift onto SJF habitat at Sand Ridge would depend on the timing and method of any applications within 200 m (656 ft) of Sand Ridge. SJF adults and eggs likely have the greatest susceptibility to pesticide drift because they live on or above the soil surface. SJF adults are potentially present from mid-August through early October (Osborne and Ballmer 2014, p. 4), while eggs generally hatch in 10 days (Rogers and Mattoni 1993, pp. 25–27; Osborne and Ballmer 2014, p. 3), thereby extending the vulnerable period to the end of October. We lack information showing pesticide application by month, or indicating the actual distance of application, but the existence of high and moderate application levels within 402 m by 402 m quarter sections that overlap Sand Ridge indicate that pesticide application could potentially be affecting the species.

Historical Range

Location South of Bakersfield: In 2006, the last year SJF were seen at the location south of Bakersfield (Osborne and Ballmer 2014, p. 2), Cholinesterase inhibitors were applied heavily (greater than 802 lbs) in the quarter-section (402 m by 402 m area) overlapping the location (CEHTP 2016, pp. 4–5). Cholinesterase inhibitors were also used the preceding year, but not as close to the site (CEHTP 2016, pp. 6–7). Accordingly, impacts from drift of cholinesterase inhibitors may potentially have contributed to extirpation of SJF at the location by 2007.

Antioch Dunes: SJF were last sighted in the vicinity of Antioch Dunes (actually 2 mi (3.2 km) to the east) in 1974 (Cazier 1985, p. 241), whereas the earliest pesticide application data we have available is 1990 (CALPIP 2016, p. 1). Consequently, the extent to which pesticides may have contributed to SJF extirpation in the area is unclear. However, there was little to no recorded pesticide application in the quarter-section overlapping Antioch Dunes in 2014. Pesticide deposition would thus be unlikely to affect any recolonization efforts of SJF at the site.

Climate Change

Current Range

Since the beginning of the 20th century, annual average air temperatures have increased in California by about 0.84 ^{o}C (1.5^{o}F) (Bales 2013, p. 2; Romero-Lankao et al, 2014, pp. 1452–1453). This has produced an irregularly increasing trend of drought severity during that time period (Cook *et al*. 2004, p. 1016). The most recent drought in the Sand Ridge area lasted for five years, from February 2012 to February 2017 (Kim and Lauder 2017, pp 2–45). For 3 years, (from January 2014 to January 2017), the drought in the area was characterized as “exceptional,” the highest level designated. Such droughts are likely to reduce the extent of the moist soil horizon in which SJF larvae live, as well as the prey base of larval insects on which SJF larvae feed. Droughts may thus lower the overall SJF larval population in a manner roughly commensurate with their duration and severity. The severity of droughts in western North America, as measured by the averaged percentage of area undergoing a drought during a given year, has roughly doubled from about 20 percent in 1900 to about 40 percent in the early 2000s (Cook *et al*. 2004, p. 1016), presumably in response to climate change. However, the specific impacts to SJF of this increase in drought severity have not been directly measured.

Increases in temperature and drought severity due to climate change may also have increased the occurrence and severity of wildfires in the recent past by drying out vegetation. A large fire during flight season could kill SJF adults or eggs, while such fires at other times of year could impact larvae by reducing the number or vigor of woody and partially woody shrubs. We are not aware of any major fires that have affected Sand Ridge, although the remains of a small fire (less than 0.4 ha (1 ac) were noted by personnel from USFWS and CNLM on August 25, 2016 (during the second week of flight season) (Tarr 2016, p. 1).

Historical Range

The most significant statewide droughts over the past century, other than the most recent, occurred during the following time periods: 1928–34, 1976–77, 1987–1992, and 2007–2009 (CDWR 2016, p. 2). While we assume these droughts negatively affected historical SJF populations, they do not coincide with any of the years during which SJF were last observed at a given site (see Table 1a, above). Nor did any such droughts occur three or fewer years prior to the last siting of SJF at a given location. Accordingly, droughts do not appear to have played a major role in the extirpation of historical SJF populations. Similarly, we have no information linking dates of last SJF sightings to fires at any of the historical locations.

<u>Conservation Actions and Regulatory Mechanisms</u>

Although no regulatory mechanisms protect the SJF directly, the population at Sand Ridge has benefitted from several mechanisms and management actions intended to protect habitat generally.

The Center for Natural Lands Management (CNLM, a private conservation organization) maintains 52.8 ha (130.5 ac) of habitat on Sand Ridge as a preserve, into which urban and agricultural development cannot expand. CDFW also maintains 2.1 ha (5.1 ac) of land on the ridge as a preserve. Vegetation overgrowth and OHV operation are not reduced in the preserve areas, however, due to lack of funding for management (CNLM 2016, p. 3).

As discussed above under Sand Mining, several regulatory mechanisms have played a part with regard to the proposed expansion of a private sand mine at Sand Ridge. The owners of the mine required a conditional use permit for the expansion due to zoning ordinances, and the permit has not yet been granted due to concerns regarding the sufficiency of the draft Environmental Impact Report, (a document required under the California Environmental Quality Act (CEQA, Cal. Pub. Resources Code 21000–21178)), and also due to potential impacts to various plants and animals protected under the Federal Endangered Species Act

(ESA, 16 USC 1531 *et seq*.) and the California Endangered Species Act (CESA, Cal. Fish and Game Code 2080 *et seq*.).

The registration and application of pesticides is regulated under the authority provided by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and its implementing regulations (7 U.S.C. §§ 136 *et seq*.; 40 C.F.R. Parts 150 *et seq*). More specific regulation of the application of each registered pesticide is provided for by the label specific to that pesticide. Adherence to the label requirements is intended to minimize or eliminate unacceptable risks to the environment from the application of a pesticide, including minimizing or eliminating risks from pesticide drift.

<u>Current Cumulative and Synergistic Effects</u>

Urban and agricultural development, and sand mining, both alter habitat to the extent that it is not usable by SJF. Vegetation overgrowth can also remove habitat from use by SJF when it is extremely dense.

The quality of SJF habitat has also been lowered by a combination of three factors: vegetation overgrowth, increased drought due to climate change, and OHV use. All these factors tend to remove woody and partially woody native shrubs important to SJF adults and larval prey species. Vegetation overgrowth and drought also lower the amount of water available to SJF larvae and their prey.

Two factors – pesticide drift and OHV operation – can directly kill SJF. Pesticide drift can kill adults when applied within 200 m (656 ft), while OHV operation can kill all other life history stages except non-neonate larvae when conducted when those stages are present.

One of the effects of small population size is difficulty in finding mates. This difficulty may be increased by the configuration of the private sand mine, which almost completely bisects the ridge, thereby separating SJF habitat into two discontinuous portions. Adults north and south of the mine may be less likely to cross the mined area and interbreed freely.

The small population size of SJF at Sand Ridge may be due to habitat loss, the poor quality of much of the remaining habitat, direct mortality, or some combination of those effects. Accordingly, any factor that contributes towards habitat loss, poor habitat quality, or direct mortality will potentially also exacerbate the problems of small population size such as inbreeding depression, difficulty in finding mates (Allee effects), and vulnerability to demographic and environmental fluctuations (stochasticity).

Drought due to climate change, and OHV operation both tend to lower the amount of vegetation overgrowth that might otherwise occur. While this effect is beneficial to SJF, it is offset: in the case of climate change by increased competition for scarce water by remaining invasive vegetation; and in the case of OHV operation by impacts to native woody shrubs and direct crushing of several SJF life-history stages.

Summary – Current Condition of the Species

SJF are historically known from eight locations across the San Joaquin Valley, but are currently restricted to portions of Sand Ridge, near Bakersfield, California. The size of the population has been informally estimated at 100 to 1,000 larvae and pupae just prior to flight season (when no adults or eggs would be present).

Urban and Agricultural Development: Over half of the total potential habitat at Sand Ridge has been developed for urban or agricultural purposes – primarily roads, citrus groves, and two sand mines (which we treat separately below). This includes habitat north of Hwy 58, which is not now considered occupied. Agricultural development was likely the primary factor leading to extirpation of the species after 2006 at a site south of Bakersfield. Urban and agricultural development also contributed to loss of habitat and eventual extirpation at the historical site of Antioch Dunes, and were likely the most important factors leading to extirpation of the historical site identified as "2 miles east of Antioch." The importance of development in the extirpation of the other four historical sites is unknown, because the exact locations of those sites has not been established, but across the San Joaquin Valley generally, over 80 percent of areas with soils conducive to SJF have been developed.

Vegetation Overgrowth: Portions of remaining habitat on Sand Ridge are being overgrown by densely growing invasive plants. These plants interfere with SJF mating activities, intercept water needed by SJF larvae, eliminate bare ground used for egg laying and eclosion. On Sand Ridge, SJF are more common at the southern end, whereas invasive plants are more common on the northern end. At Antioch Dunes, invasive vegetation has been identified as the primary cause of extirpations of other dune-dependent insects. The extent of impacts from vegetation overgrowth at other historical sites is unknown, but various species of invasive grasses similar to those at Sand Ridge are present across the historical range.

Sand Mining: Two sand mines, one private and one County-owned, currently operate at Sand Ridge. The County mine is relatively small and has been decreasing its operations for several years, but the private mine has expanded past its permitted area, and has applied to the County to expand further. The application was referred to the County Planning Department for further analysis in 2013. At Antioch Dunes, sand mining greatly reduced the extent and height of the dune habitat, and likely played a primary role in the extirpation of SJF at the site. Sand mining is not known to have affected other SJF sites, although the exact location of most of those sites is not known.

Off-Highway Vehicles: OHVs can crush SJF life history stages other than older larvae (which are deep-burrowing), and can destroy important habitat features such as woody shrubs. More positive effects include removal of invasive plants, but careful management would be required for this to result in an overall beneficial impact, if such were even possible. OHV use occurs at two primary locations on Sand Ridge, each encompassing approximately 1 ha (2.5 ac). Aerial imagery shows likely impacts both to native woody plants and to invasive grasses. Effects of OHV use at historical locations are unknown.

Climate Change: Drought severity has increased since 1900 in conjunction with increasing average temperatures. The most recent drought at Sand Ridge lasted for 5 years, beginning in 2012, and was "exceptional" (the most severe category) for 3 years beginning in 2014. This has likely impacted the SJF population due to losses of moist soil substrate and larval insect prey. The likelihood and impacts of wildfires can also be increased by climate change, but we are not aware of any major fires at Sand Ridge or other historical locations.

Small Population Size: The size of the Sand Ridge population has been estimated at 100 to 1,000 individuals just prior to flight season. Because not all larvae become adults in a given year, and because adults live only about 3 days during a 49 day flight season, the population may not be large enough for adults to be sure of finding mates, or to avoid inbreeding depression, or to recover from chance variations in the environment or in the sex ratio or individual reproductive output. The relatively slow decrease in sightings at the Antioch Dunes historical location prior to extirpation suggests these issues of low population size may have affected it as well.

Pesticide Drift: SJF are potentially susceptible to windborne drift from pesticides applied within 200 m (656 ft) of Sand Ridge during or just after flight season (mid-August through mid-October). In 2014, cholinesterase inhibitors were applied heavily, and nicotinoids were applied in moderate amounts, within the four quarter-section areas (402 by 402 m) overlapping Sand Ridge, but we have no information regarding the methods of application, the days applied, or the specific locations of use within the overlapping quarter-sectional area. Cholinesterase inhibitors were also applied heavily in the quarter-sectional area overlapping the historical SJF site south of Bakersfield the year prior to extirpation of SJF at the site. Effects from pesticide drift are likely intermittent, occurring some years and not others depending on whether a given pesticide is being applied upwind during flight season within the susceptible distance.

FUTURE CONDITION OF THE SPECIES

We consider here how the factors discussed above with regard to current viability may affect the viability of the SJF in the future. The future timeframe we are considering here is 50 years, which we chose because it is within the range of available climate change models, and allows for reasonable extrapolations of current trends.

Climate Change

Within 50 years, global CO_2 concentrations of 560 ppm are projected under two of four basic types of Representative Concentration Pathways (CO_2 emission and mitigation scenarios) (Moss *et al*. 2007 pp. 34, 45). In the San Joaquin Valley, concentrations of 550 ppm are expected to produce average temperature increases of about 1.1 °C (2.0 °F). Accordingly, we expect average temperatures at Sand Ridge to increase roughly 1.1 °C (2.0 °F) within 50 years. We do not expect that to strongly affect SJF directly, because SJF spend most of their lives underground.

Average annual precipitation in the Sand Ridge area is also likely to decrease by 1.4 cm (0.55 in per year) (Bell *et al*. 2004, p. 86), down to about 15 cm (5.9 in) per year (US Climate Data 2017, p. 1). Of seven woody or partially woody plants at Sand Ridge important to SJF larvae (see Life History – Larvae, above), the ranges of four (California buckwheat, California croton, ephedra, and cheeseweed) extend into areas receiving 12.7 cm (5 in) or less rainfall per year. We therefore expect those species to persist at Sand Ridge for the next 50 years despite climate change, although the number of individual plants may decrease. The remaining three native shrubs (brittlebush, telegraph weed, and scale broom) do not grow in areas receiving 12.7 cm (5 in) or less of rain, but could potentially still grow at Sand Ridge, where rainfall is expected to decrease to 15 cm (5.9 in) per year. Because total numbers of deep-rooted plants are likely to decrease, and some species may be lost from the area entirely, maximum population levels for subterranean prey species may be lowered, thereby also lowering maximum population levels of SJF larvae.

Changes in precipitation are also likely to affect vegetation overgrowth, as discussed under <u>Vegetation Overgrowth</u>, below.

Annual precipitation is likely to vary significantly around the average, resulting in droughts. A recent study combining information from both historical precipitation levels and projected Representative Concentration Pathways (CO2 emission and mitigation scenarios), found risks of decadal droughts (11 or more years) in the Bakersfield area to be 50 to 80 percent between now and 2100 (Ault *et al*. 2014, p. 7541). Risks of multidecadal droughts (35 or more years) ranged from 10 to 30 percent (Ault *et al*. 2014, p. 7542). Such droughts would be likely to lower SJF population numbers by reducing the extent of moist soil horizon available for larvae and their prey, and by reducing the number and vigor of woody and partially woody shrubs on which SJF larval prey depend. Such effects would tend to be exacerbated by nonnative invasive vegetation, which would compete with the woody and partially woody shrubs for the scarce water, and which might also prevent some water from soaking down into the moist soil horizon where SJF larvae develop. While SJF have likely weathered such serious droughts in their evolutionary past, they almost certainly would have entered those droughts with multiple large populations occupying larger dune systems that were unaffected by nonnative introduced vegetation.

Increased average temperatures, decreased average precipitation, and prolonged drought will also tend to dry out vegetation, thereby increasing the risk of fire at Sand Ridge. Large fires occurring during flight season could kill SJF adults or eggs, while such fires at any time of year could impact larvae by reducing the number or vigor of woody and partially woody shrubs.

<u>Urban and Agricultural Development</u>

Remaining SJF habitat at Sand Ridge consists of roughly 106.8 ha (264 ac). Just over half of this (53.7 ha (132.7 ac)) is in private or state preserves while about 48.7 ha (120.3 ac) is on private property zoned for agriculture. Additional habitat includes approximately 2.5 ha (6.1 ac) of County land surrounding the County-owned sand mine but not yet disturbed, and 2.0 ha (4.9 ac) of right-of-way land abutting Highway 58.

County permits are not required for property owners to convert their Sand Ridge lands to agriculture (Cates 2017, p.1). Accordingly agricultural development is more likely than urban over the next 50 years.

Based on aerial photographs, the most recent development on the ridge south of highway 58 involved conversion of land for row crops on approximately 7.7 ha (19 ac) of habitat in the northern portion of the ridge from about 2009 through about 2012. Three additional patches totaling about 16 ha (40 ac) of habitat north of Highway 58 were converted prior to 2005, which is the earliest date for which we have such data. Habitat north of Highway 58 is now primarily converted to agriculture, and no SJF are known to occupy the little that remains.

Based on the agricultural conversion that has occurred to date, we have considered two alternative conversion rates for future habitat conversion. The more pessimistic rate assumes areas of habitat equal to the amount most recently converted (7.7 ha (19 ac)) will be lost roughly every 10 years. This would mean a total of about 38.5 ha (95.1 ac), or 36 percent of the total current habitat, would be lost to development over 50 years' time. Under the more optimistic scenario increased water scarcity and difficulties grading or building on the higher ground of the ridge might restrict development to perhaps a third of the previous estimate, or about 13 ha (32 ac) after 50 years. We consider the second scenario somewhat more likely due to increased water scarcity under climate change, and due to the likelihood that areas that were easier to develop have been converted first, leaving unconverted areas that are somewhat more difficult to develop. The percentage loss of habitat under this optimistic scenario would be about 12 percent of total remaining habitat.

Sand Mining

As discussed under **Current Condition of the Species**, above, in 2013 the company operating the larger of two sand mines at Sand Ridge submitted an application, which is still pending, to expand their mine to 17.5 ha (43.25 ac). This would cover the entire extent of their property. 15.1 ha (37.25 ac) of that propergy is on the ridge, and so is SJF habitat. The remaining 2.4 ha (6.0 ac) extends east of the ridge, and so is not SJF habitat. The sand mine currently occupies 8.2 ha (20.3 ac), so the expansion would cause the loss of about 6.9 ha (16.95 ac).

We considered likely impacts if the mine does expand in the next 50 years, and if it does not.

Under the more pessimistic scenario, either the County would eventually approve the application or the mine would expand to the requested extent without a permit (as it has expanded in the past). In that case, approximately 6.9 ha (16.95 ac) of habitat will be permanently lost. Habitat lost to expansion of sand mining would likely be of relatively high quality, as it is in the southern third of the ridge where SJF adults have been observed in greater density, and which generally has less invasive vegetation (Osborne and Ballmer 2014, p. 6; Van Dam 2017, p. 1).

An expansion of the existing sand mine would also widen the gap between SJF habitat south and north of the mine, potentially making it more difficult for adults to freely mix when choosing mates (see *Small Population Size*, below). Additional impacts would occur as discussed below for the alternative scenario. We consider this the more likely scenario, given the mine's history of expansion without regard to permitted boundaries.

Alternatively the County would not approve the permit, and the mining company would not expand the mine further. In that case sand mining would continue to its current extent, with its current impacts discussed above. It would also be likely to cause low-level impacts to surrounding SJF habitat by removing additional sand and thereby creating a moisture sink into which water from the moist soil horizon outside the mined area would flow and be lost. Additionally, SJF larvae would be expected to occasionally burrow into the mined area and adults would occasionally lay their eggs within it, resulting in direct losses of SJF to mining equipment. Pollution of the aquifer due to spilled oil or gas would also be a possibility.

Off-Highway Vehicles (OHVs)

At current growth rates, the population of Kern County will double by 2050, subject to a wide variety of factors, such as water availability and economic opportunities, that could delay or accelerate that date (KEDC 2015, p.1). This may lead to an increase in OHV use at Sand Ridge.

As discussed above under **Current Condition of the Species**, OHV use is currently known to be an issue on and just north of the preserved lands owned by the Center for Natural Lands Management (CNLM), and on land just east of the northern portion of the private sand mine. It appears to have most appreciably altered habitat in the latter area, where numerous dirt-bike trails have removed both native and invasive vegetation.

Based on population growth projections for the county, we consider the most likely scenario for OHV use at Sand Ridge would be roughly a doubling of such activity over the next 50 years. That would result in a decline in habitat quality over approximately another 2 ha (5 ac), along with increased crushing of SJF eggs, neonate larvae, pupae, and newly eclosed adults in the areas used.

We consider the second most likely scenario to involve efforts by landowners to limit additional OHV use, resulting in no significant increase or decrease in such activity overall. In that case, effects would continue as discussed under Current Impacts, above.

Vegetation Overgrowth

Over the next 50 years, the extent of overgrowth of open sandy areas by nonnative vegetation will depend primarily on the amount of precipitation, which in turn is affected by climate change. At CO_2 concentrations of 560 ppm (which is projected within 50 years under two of four basic types of Representative Concentration Pathways (CO_2 emission and mitigation scenarios) (Moss *et al*. 2007 pp. 34, 45), total rainfall in the hydrologic basin that includes Sand Ridge is expected to decrease by 1.4 cm per year (0.55 in per year) (Bell *et al*. 2004, p.

86). Average annual rainfall in the Bakersfield area is currently 16.4 cm (6.45 in) (US Climate Data 2017, p. 1), so under those conditions it would drop by about 8.5 percent, to 15 cm (5.9 in) per year. A comparison of rainfall patterns in southern California (OCS 1995, p. 1) with range maps for nonnative invasive vegetation species at Sand Ridge (Ripgut brome (*Bromus diandrus*), Saharan mustard (*Brassica tournefortii*), wild oat (*Avena fatua*), and red brome (*Bromus madritensis ssp. rubens*) (Calflora 2017, pp. 1–4) indicates that all four invasive species are known from areas with average annual rainfall of 12.7 cm (5 in) or less. Accordingly, the nonnative invasive species responsible for vegetation overgrowth at Sand Ridge are likely to maintain their presence over the next 50 years, despite climate change.

The extent to which invasive vegetation occupies habitat on the ground may potentially be reduced by reductions in precipitation, however. We lack data showing the relationship between these parameters, and so consider potential impacts if the extent of vegetation overgrowth remains unchanged (pessimistic scenario) and if the area and density of overgrowth is reduced by about 8 percent due to the projected 8 percent drop in precipitation. This may provide a small improvement to the SJF population by increasing the amount of bare-sand habitat.

In the former case, nonnative vegetation would continue to remove open areas needed by SJF for mating and egg laying. The impacts of such vegetation on larvae would likely increase, since available water would decrease, but the same amount of non-native vegetation would be competing for it. This would decrease the available extent of moist soil substrate used by larvae and their prey species, and would also tend to decrease the number of deep-rooted shrubs important to SJF larval prey species.

Under the second scenario, non-native vegetation would decrease in accordance with decreases in precipitation, leaving overall impacts from competition roughly the same. New areas of bare sand habitat would be exposed, however, leading to somewhat improved habitat for mating and egg-laying activities. We consider this scenario to be more likely, since precipitation appears to be a limiting factor on the extent of nonnative vegetation currently at the site.

<u>Pesticide Drift</u>

Although the population of Kern County is increasing, and may double by 2050 (KEDC 2015, p.1), the Kern County General Plan establishes protection of agricultural lands as a planning goal (KCPD 2009, pp. 52–53). Land use maps for the Kern County and Metropolitan Bakersfield general plans show the lands within 5 miles of Sand Ridge planned primarily as intensive agriculture (City of Bakersfield 2002, p. 1; KCPD 2009, pp 53–54; KCPD 2010, p.1). Accordingly, those agricultural areas that are currently within 200 m (656 ft) of SJF habitat on Sand Ridge, and thus of concern as possible sources of pesticide drift (see Current Condition of Species, above), are likely to stay in agricultural production for the next 50 years. Most of the land to the east of Sand Ridge within 200 m (656 ft) is currently in two preserves, however, rather than in agricultural production. One of those preserves is operated by CDFW and the other by the Center for Natural Lands Management. Under the most likely scenario, those lands would remain in a natural state, and impacts from pesticide drift would remain unchanged. Under a more pessimistic scenario, one or both of these currently protected areas would be converted to agriculture within 200 m (656 ft) of Sand Ridge, thereby increasing the potential for impacts to SJF from pesticide drift. We are not aware of any existing efforts to purchase or otherwise acquire those lands for agriculture, and so consider the more pessimistic scenario unlikely.

<u>Small Population Size</u>

As discussed under **Current Condition of the Species**, above, the SJF population may currently be small enough to be at risk from inbreeding depression, Allee effects, demographic stochasticity, or environmental stochasticity. Once any of these effects produce serious impacts, it becomes difficult for the population to recover. Accordingly, an optimistic scenario would involve the population staying large enough over the next 50 years to avoid any such impacts. Under a more pessimistic scenario, however, the population size might fall at some point within the next 50 years to levels at which any of the effects mentioned above would have serious effects. This is the more likely case, both because population sizes tend to fluctuate over time, and because of likely continuing or increasing impacts from other sources as discussed above.

<u>Future Cumulative and Synergistic Effects</u>

All future cumulative and synergistic effects are as discussed above under <u>Current Cumulative and Synergistic Effects</u> (see also: Cumulative and Synergistic Effects Table, p. vi above). However, areas of habitat that are currently suffering from reduced quality may in the future become totally removed as SJF habitat due to development or expansion of sand mining. It is potentially possible that some areas currently removed as SJF habitat due to dense vegetation overgrowth may become low-quality habitat in the future as the density is reduced due to droughts resulting from climate change. These localized improvements would likely be offset by increased competition for scarce water by invasive vegetation across the range, however.

<u>Summary – Future Condition of the Species</u>

Climate Change: Increases to average temperature and decreases to average annual precipitation will likely have little impact, but increases in the likelihood and severity of droughts are likely to produce serious impacts. Such impacts include reduction of the moist soil horizon required by SJF larvae; reduction of larval insect prey base, and of the woody plants supporting that prey base; and increases in wildfire, which in turn further reduce the woody plants supporting SJF prey species.

Urban and Agricultural Development: We consider the loss of additional habitat due to agricultural conversion to be likely in the next 50 years. The amount lost may be in the vicinity of 13 ha (32 ac), which would constitute about an eighth of existing habitat.

Sand Mining: The existing privately owned sand mine may expand operations over an additional 6.9 ha (16.95 ac) within 50 years. This would remove some of the highest quality remaining habitat, as it is less covered by invasive vegetation. Continued operation of both existing mines may also affect SJF in nearby habitat by draining off water, and by direct impacts to larvae entering the area or eggs laid in the area.

Off-Highway Vehicles: OHV use might reasonably be expected to double over the next 50 years, potentially doubling the area of impacted habitat (to a total of 4 ha (10 ac), and directly crushing additional SJF in vulnerable life history stages such as eggs and pupae.

Vegetation Overgrowth: Nonnative vegetation will continue to remove available water from the moist soil horizon where it needed by larvae and woody shrubs that support larval prey species. However, we consider decreases in precipitation (due to climate change) likely to result in commensurate decreases of about 8 percent in the density and extent of invasive vegetation. This will somewhat increase the availability of open sandy patches required for mating and egg-laying.

Small Population Size: At some time in the next 50 years, SJF population size at Sand Ridge is likely to fall below the point at which serious impacts occur. Those impacts include inbreeding depression, difficulties in finding mates, and vulnerability to demographic and environmental stochasticity. After those impacts occur, recovery to a more healthy population size within will be relatively unlikely within 50 years

Pesticide Drift: Nearby agricultural lands are likely to remain in agriculture for the next 50 years. There is potential for additional land east of the Ridge to be converted to agriculture, but we consider this unlikely. Impacts from pesticide drift are thus likely to remain unchanged.

SPECIES VIABILITY

As discussed above under Resource Needs of SJF Relevant to the Species as a Whole, the continuing viability of a species depends on the resiliency of each population, the redundancy provided by multiple populations, and the degree to which those redundant populations provide representation for the entire range of the species.

Resiliency

Population size at the Sand Ridge population is likely restricted by available habitat, which in turn is restricted by agricultural development, sand mining, and vegetation overgrowth. Agricultural development and sand mining are likely to increase in the future, while vegetation overgrowth may decrease somewhat due to climate change. The population (as considered just before flight season) is currently estimated at 100 to 1,000 individuals, about half of which will become adults in a given year. Because flight (mating) season lasts about 7 weeks, and adults only live about 3 days, many adults will be unavailable to mate with many others whose eclosion times are not close enough together. This may leave the effective size of the population considerably smaller than the estimated census size, and thus more subject to impacts from inbreeding depression, and environmental or demographic stochastic changes. Those issues are likely to impact the population in the future as well, as impacts from other sources, or simple fluctuations in population size over time, potentially cause the population size to drop below the point at which such small-population concerns become important. Climate change is also likely to impact the population in the future, due both to decreases in average precipitation, and to increased droughts.

In addition to the major potential factors affecting population resiliency discussed above, we also considered pesticide drift and impacts from OHVs. Pesticide drift would have to occur upwind, during or just after flight season, and from within 200 m (656 ft) to have an impact. This may occur during some years but not others. OHV use would tend to remove invasive grasses, which would benefit SJF, but at high levels it would also tend to remove native woody shrubs, which would negatively affect SJF. Neither of these factors is likely to have a major impact on population resiliency within 50 years.

Redundancy

Although eight total SJF populations have been known historically from scattered locations across the San Joaquin Valley, all but the Sand Ridge population have been extirpated (see Tables 1a and 1b, above). The most recent such population to be lost was about 16 km (10 mi) south of Bakersfield, where SJF were found until 2006. Scattered locations with appropriate habitat still exist in the San Joaquin Valley, and to the extent possible these should be surveyed for SJF, but based on the best information currently available, Sand Ridge supports the only remaining SJF population. Loss of the Sand Ridge population would thus very likely mean loss of the species.

Representation

Populations can become adapted to local habitat conditions that differ across their entire range. Loss of populations in one portion of the range may thus lead to loss of those local adaptations, which the species as a whole may need in the future to help it adapt to changing conditions. The eight historical SJF locations differed slightly in average temperatures, seasonal variations, and precipitation (see Additional Demographic Needs of the Species, above). Differences in resistance to disease, or in larval prey species, were also possible. That historical range of differences is no longer supported by the single remaining population.

APPENDIX A: PEER REVIEW

We contacted five entomologists with backgrounds involving flies (Diptera) or the conservation biology of insects, and asked them to review an advance draft copy of this report. We explained the purpose of this SSA (to inform our decision regarding listing of the SJF under the Endangered Species Act), and asked them specifically: (1) whether we had considered the best relevant scientific and commercial information; (2) whether our analysis of the information was correct; and (3) whether our conclusions were reasonable in light of the information.

We received one review. The reviewer indicated that we had considered the best information, and that our conclusions were largely correct, but thought we had underestimated the negative impacts of OHV operation and sand mining at Sand Ridge. We have revised the SSA to incorporate the reviewer's comments.

APPENDIX B: SJF POPULATION STRESSORS, CONSERVATION MEASURES, AND ASSOCIATED LISTING FACTORS FROM THE ESA (SEC. 4(A))[1]

ESA Listing Factor	Potential Stressor	Conservation Measures
Factor A	Urban and agricultural development	Private and County preserves totaling 54.9 ha (135.6 ac) of habitat.
Factor A	Vegetation overgrowth	
Factors A & D	Sand mining	Conditional use permit for mine expansion currently under review by County. However, the mine has expanded 4.3 ha (10.6 ac) beyond its permitted area despite the lack of permit.
Factors A & E	Off-highway vehicles	
Factor A	Climate change	
Factor E	Small population size	
Factor E	Pesticide drift	Application methods regulated under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (7 U.S.C. §§ 136 *et seq.*; 40 C.F.R. Parts 150 *et seq*).

[1] Factor A: The present or threatened destruction, modification, or curtailment of its habitat or range.
Factor B: Overutilization for commercial, recreational, scientific, or educational purposes.
Factor C: Disease or predation.
Factor D: The inadequacy of existing regulatory mechanisms.
Factor E: Other natural or manmade factors affecting its continued existence

Appendix C: Acreage, Ownership, and Uses of Sand Ridge Parcels South of Hwy 58

Total Acreage: 143 ha (343.3 ac)

Total Currently Developed: 32.1 ha (79.3 ac)

- Private sand mine:
  - Currently developed: 8.2 ha (20.3 ac)
    - Authorized: 5.3 ha (13 ac)
    - Expansion Request: to 17.5 ha (43.25 ac)
    - Total company land on ridge (potential lost SJF habitat): 15.1 ha (37.25 ac)
- County sand mine:
  - Currently developed: 3.6 ha (9.0 ac)
- Developed for Agriculture:
  - Northern two agricultural areas: 15.1 ha (37.3 ac)
  - Northern orange grove: 5.1 ha (12.7 ac)

- Note: Does not include
  - OHV areas – reduced habitat quality: 2 ha (5 ac)
  - Microwave station & parking: 0.4 ha (1 ac)

Total Undeveloped: 106.8 ha (264.0 ac)

- Preserves
  - CNLM: 51.7 ha (127.7 ac)
  - County: 2 ha (5 ac)
- Unprotected potential habitat: 53.1 ha (131.3 ac)
  - Undeveloped Kern County land around mine: 2.5 ha (6.1 ac)
  - Undeveloped Hwy 58 right-of-way: 2 ha (4.9 ac)
  - Undeveloped private land: 48.7 ha (120.3 ac)

APPENDIX D: MAP OF SAND RIDGE, WITH OWNERSHIP AND USES